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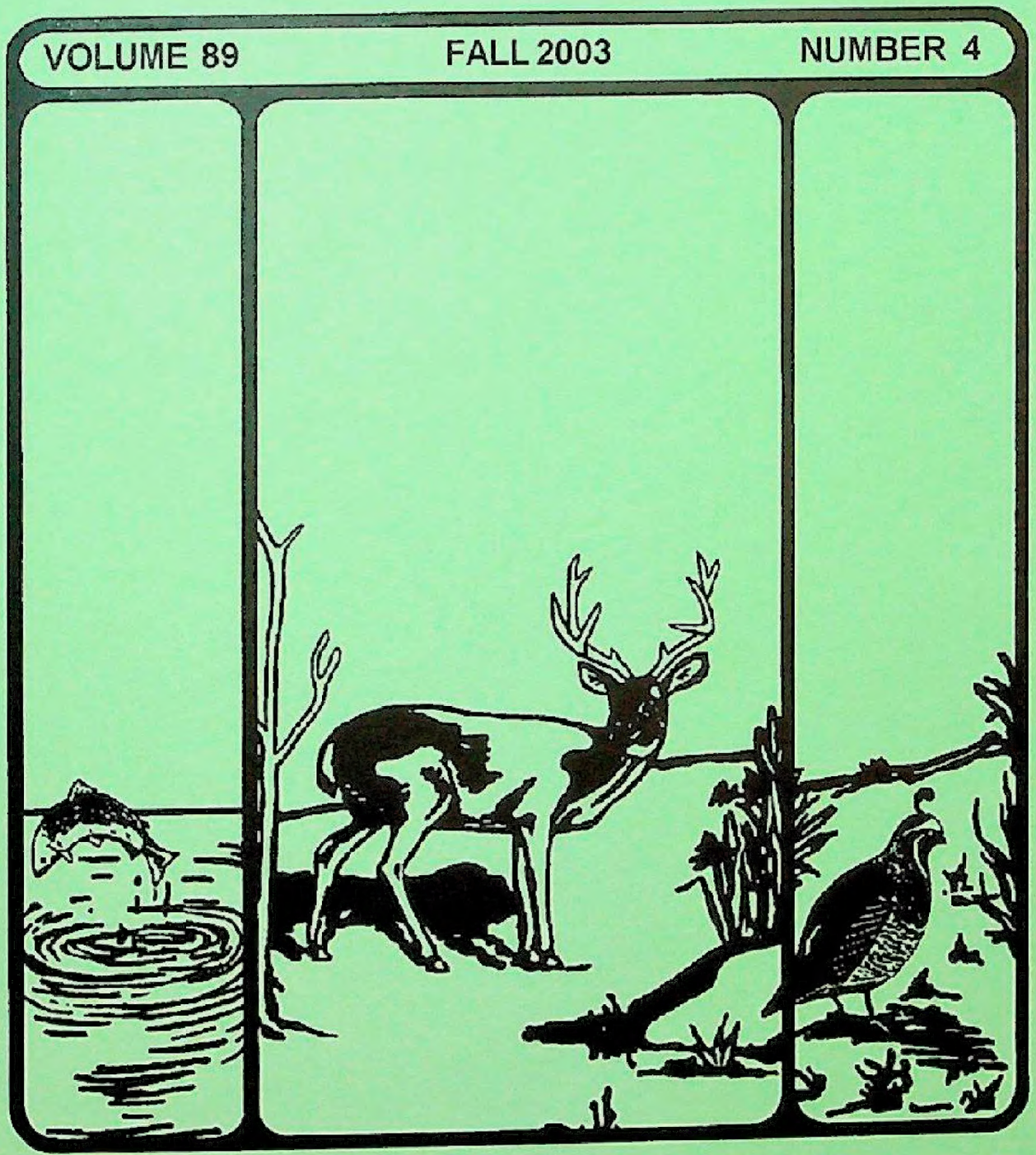

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RESPONSES OF LANDBIRDS TO GROUP SELECTION LOGGING IN THE CENTRAL SIERRA NEVADA

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Responses of landbirds to group selection logging were studied using mist-nets and bird banding at two 10.6-ha stands between 1996-2001 in the central Sierra Nevada, California. One randomly selected stand was cut (treatment) in June 1999, and the adjacent stand remained uncut (control). The stands had similar pre-harvest vegetation attributes, except that the treatment stand had greater densities of hardwoods in the shrub layer (P =0.003). The control stand had more *Ceanothus* (P <0.005). Harvesting removed approximately 25 % of the basal area (m^2/ha) and live tree stems. There were greater (P <0.008) differences in capture totals for all birds, young-of-the-year (HY) birds, and total number of bird species during the postharvest period. More birds were captured in the treatment stand and fewer birds were captured in the control stand during the postharvest period. When adjusted for total monthly precipitation from May-August, however, bird captures did not differ (P >0.141) between stands and treatment periods. Between-stand differences in captures of all birds and HY birds, however, were different (P <0.041) between the pre- and postharvest periods when adjusted for monthly precipitation. There was a seasonal population trend with greater bird numbers in May and June, months with the greatest precipitation, and least in July and August, months with the least precipitation (P <0.001). Movements within and between stands were similar for the pre- and postharvest periods for 7 species with ≥10 recaptures. We concluded that group selection harvesting at this site did not have a negative effect on landbirds present during the breeding season except for the first postharvest year when bird captures declined in both stands. Bird numbers fluctuated with precipitation,

however, so it appears that populations were affected by interactions between habitat and precipitation.

INTRODUCTION

There is considerable recent interest in conserving and managing forest resources of California's Sierra Nevada as two major resource assessments have been recently conducted (Centers for Water and Wildland Resources[1] 1996, U.S. Forest Service[2] 2001). These assessments concluded that logging was variously affecting the regions's forested wildlife habitats. Impacts to wildlife from logging are important considerations for forest managers in the Sierra. Whether logging occurs on public or private lands, guidelines and regulations exist to ensure that wildlife needs are considered when logging operations are planned and conducted. Rarely, however, are these guidelines and regulations evaluated with field investigations of wildlife responses. Landbirds, mostly birds from the Orders Piciformes and Passeriformes, are important and conspicuous residents of forest habitats so impacts from logging to landbirds are often evaluated (Morrison 1986, Sallabanks et al. 2000).

Group selection logging where groups of trees are harvested from small areas (<1 ha) has been recommended as a logging technique in the Sierra Nevada because it is thought to minimize impacts to wildlife and enhance site conditions for germination, sprouting, and growth for hardwoods and other tree species favoring openings in the forest canopy (McDonald and Tappenier[3] 1996). Group selection logging creates habitat conditions favoring fall-migrant birds using small canopy openings (Kilgo et al. 1999). No studies to date, however, have been conducted on wildlife impacts from group selection logging in Sierra Nevada habitats where hardwoods such as California black oak, *Quercus kelloggii*, are major components of these forests.

To evaluate effects of group selection logging to landbirds in California black oak-dominated forest habitats in the Sierra Nevada, we did this study using bird banding as a method to measure landbird responses. Studies of impacts to landbirds from logging are generally conducted using counts of birds where species composition and populations are compared (Marzluff et al. 2000, Sallabanks et al. 2000). Bird banding is another way to quantify landbird responses by not only measuring population and

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[1] Centers for Water and Wildland Resources. 1996. Sierra Nevada Ecosystem Project, final report to Congress, Volume I, assessment summaries and management strategies. University of California, Centers for Water and Wildland Resources, Report No. 36, Davis, California, USA.

[2] U.S. Forest Service. 2001. Sierra Nevada Forest Plan Amendment, final environmental impact statement, chapters 1 and 2. U.S. Department of Agriculture, Forest Service, Pacific Southwest Region, San Francisco, California, USA.

[3] McDonald, P. M. and J. C. Tappeiner. 1996. Silviculture-ecology of forest-zone hardwoods in the Sierra Nevada. Pages 621-636 *in:* Sierra Nevada Ecosystem Project, final report to Congress, Volume III, assessments, commissioned reports, and background information. University of California, Centers for Water and Wildland Resources, Report No. 36, Davis, California, USA.

community parameters but also possibly recording bird movements and demographic parameters (Ralph et al.[4] 1993, Remsen and Good 1996, Silkey et al. 1999). Our null hypothesis was that group selection logging had no impact on landbirds. Using a pair of treatment and control stands and banding during preharvest and postharvest periods, we measured responses of landbirds using frequencies of captures and movements of recaptured birds between the two stands.

STUDY AREA

We conducted this study between 1996-2001 on two 10.6-ha study stands that were adjacent to each other in southern Placer County, California. Both stands were at 1,280 m elevation, aspects were west, and slopes <5%. The stands was located on a plateau atop the canyon of the Middle Fork of the American River and were located in a much larger homogeneous forest stand. The study stand had a tree layer dominated by large diameter (>51 cm diameter breast height [dbh]) California black oak and ponderosa pine, *Pinus ponderosa*. Other less dominant tree species included Douglas-fir, *Pseudotsuga menziesii*, white fir, *Abies concolor*, sugar pine, *P. lambertiana*, and incense cedar, *Calocedrus decurrens*. Seedling and sapling California black oak and ponderosa pine dominated the subcanopy. The shrub layer was generally sparse, and deerbrush, *Ceanothus integerrimus*, and sapling California black oak were the most common shrubs. The herbaceous layer was dominated by occasional dense patches of mountain misery, *Chamaebatia foliolosa*.

Group selection logging was conducted over a 1-week period in early June 1999 in one randomly selected stand, and the adjacent stand was an unharvested control. Logging was done on four 0.6-ha circular harvest units in the treatment stand. The harvest units were randomly selected from 15 0.04-ha vegetation sampling points that were randomly placed on a 25-m x 25-m sampling grid (see below). The total area harvested was 2.4 ha, which represented 23 percent of the treatment stand's total 10.6-ha area. All commercial sized trees >20 cm dbh were cut in the harvest units.

METHODS

Each stand had 11 2.6-m x 12-m mist nets with 36-mm mesh, and banding was done in both stands during a preharvest period (1996 to 1999) and a postharvest period (1999 to 2001). In all years banding was conducted between May to August on 12 banding days each per stand per year on 4-15 day intervals (average = 9.5 days). Both stands were simultaneously banded during banding days, and nets were open continuously for a 6-hour period beginning 15 minutes before official sunrise. Nets were opened and

[4] Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, General Technical Report PSW-GTR-144, Albany, California, USA.

closed in the same sequence over all years and all banding days. Nets were closed when temperatures exceeded 32°C and banding was not done on days with rain, snow, or high winds.

We followed protocols established by the Monitoring Avian Productivity and Survivorship Program (MAPS), a national program monitoring productivity and survivorship of breeding landbirds in North America (DeSante and Burton[5] 1997). Nets were placed for complete and even coverage in each stand while simultaneously maximizing distance between nets and maximizing capture opportunities by placing nets in areas where bird occurrence and movements appeared prominent. The stands were very homogeneous with similar vegetation and physical conditions (see Table 1) within and between stands, and there were innumerable locations in both stands where nets could be placed. A 37.5-m buffer existed around the periphery of each stand such that nets were concentrated in a 6-ha area within the 10.6-ha stand. Mist nets were placed in both stands before random selection of the treatment stand and individual harvest units so there were no *a priori* decisions made about net locations relative to harvest units. Because of locations of the nets relative to the harvest units, study results represent stand-level responses to the treatment, not responses to the individual harvest units. Net locations were fixed during the 6-year study period so hypothesis tests of differences in bird captures between stands and the treatment period resulted from differences in captures at the 11 nets in each stand.

The primary response variable for each banding day was the sum of the number of birds captured for the first time, the number of birds recaptured for the first time subsequent to the year of initial banding, and the number of birds recaptured for the first time in the adjacent stand in the year of initial banding as was done by Krementz and Christie (1999). Totals were determined for all birds captured at all 11 nets within each stand on each banding day. For example, capture totals for 1997 and 1998 would include a bird initially banded in 1996 and recaptured once 1997 and 1998, respectively. Each captured bird was banded with a U.S. Fish and Wildlife Service band and examined to determine species, age, and sex using Pyle et al. (1987) between 1995-1997 and Pyle (1997) between 1998-2001. All adult birds and young-of-the-year (Hatch Year = HY) from all species that were captured in the stands were combined in the capture totals to analyze treatment effects on the entire bird community. A separate analysis was done to determine if the treatment affected avian productivity using only HY birds from yearlong and summer breeding residents in the study stands (defined in Table 1). Species richness from all species was also determined for each banding day as another measure of the bird community.

We used an experimental design known as BACIP (before-after/control-impact - pairs) (Stewart-Oaten et al. 1986 and 1992) where differences in response variables between treatment and control stands for a preharvest and a postharvest period are compared using two-sample t-tests. Analyzing differences this way is necessary

[5]DeSante, D. F. and K. M. Burton. 1997. MAPS manual: instructions for the establishment and operation of stations as part of the Monitoring Avian Productivity and Survivorship Program. The Institute for Bird Populations, Point Reyes Station, California, USA.

Table 1. Vegetation (mean ± SE) attributes of two 10.6-ha stands (n = 8-15 per attribute) in Placer County, California.

	Treatment		Control		t-test comparison *P*-values			
					Pre-Post[a]		Pre-Pre[b]	Post-Post[b]
Attribute	Preharvest	Postharvest	Preharvest	Postharvest	T-T[c]	C-C[c]	T-C	T-C
Tree diameter (cm)								
All trees	31.4 ± 2.2	29.3 ± 1.8	36.5 ± 3.2	40.1 ± 3.1	0.150	0.024	0.229	0.005
Hardwoods	67.8 ± 8.6	65.3 ± 8.6	57.1 ± 9.7	59.5 ± 8.2	0.703	0.712	0.429	0.643
Conifers	23.4 ± 1.2	22.1 ± 1.4	29.5 ± 2.8	31.4 ± 2.8	0.192	0.065	0.073	0.007
Tree height (m)								
All trees	14.2 ± 1.2	15.0 ± 1.1	17.3 ± 1.8	17.5 ± 1.3	0.239	0.741	0.157	0.147
Hardwoods	18.9 ± 1.3	24.2 ± 2.1	17.2 ± 2.3	16.0 ± 1.8	0.069	0.386	0.452	0.008
Conifers	13.5 ± 1.3	13.1 ± 1.2	16.3 ± 1.8	17.4 ± 1.5	0.747	0.310	0.230	0.023
Tree density (#/ha)								
All trees	378.9 ± 46.1	280.0 ± 36.6	275.1 ± 30.0	248.7 ± 27.2	0.004	0.103	0.065	0.596
Hardwoods	74.1 ± 17.7	47.8 ± 14.0	39.5 ± 11.8	46.1 ± 11.8	0.054	0.068	0.075	0.796
Conifers	304.8 ± 53.6	232.3 ± 37.8	235.6 ± 31.1	202.6 ± 28.9	0.007	0.027	0.317	0.601
Basal area (m^2/ha)								
All trees	36.9 ± 3.8	26.3 ± 4.0	39.6 ± 6.6	38.3 ± 4.5	0.018	0.691	0.945	0.047
Hardwoods	23.8 ± 4.6	16.5 ± 3.9	15.2 ± 6.0	16.9 ± 5.8	0.041	0.142	0.087	0.702
Conifers	13.1 ± 1.7	9.8 ± 1.8	24.4 ± 6.6	21.4 ± 4.8	0.019	0.386	0.234	0.062
Shrub density (#/ha)								
All shrubs	3,575 ± 804	4,781 ± 918	2,247 ± 804	2,489 ± 884	0.311	0.979	0.141	0.065
Ceanothus	106 ± 79	75 ± 48	980 ± 336	543 ± 335	0.983	0.069	0.005	0.171
Hardwoods	2,881 ± 643	4,314 ± 892	860 ± 630	1,538 ± 756	0.205	0.079	0.003	0.019
Conifers	589 ± 246	392 ± 206	347 ± 125	407 ± 186	0.482	0.833	0.533	0.938

[a] Paired sample t-test (df = 14) comparison of vegetation attributes between preharvest and postharvest values in the same stand.

[b] 2-sample t-test (df = 14.5-26.7) for separate variance comparisons of vegetation attributes between both stands in the preharvest and postharvest periods, respectively.

[c] T = treatment stand; C = control stand.

because of the paired nature of the treatment and control stands and the need to account for natural differences between the two stands and changes that might influence both stands concurrently. This design assumes that differences are additive between the pre- and postharvest periods and independent between banding days. Transformations [$\log_{10}$ (captures+1)] and autocorrelation analysis using the Durbin-Watson statistic were used to address these assumptions (see below) (Stewart-Oaten et al. 1986).

Differences in captures of all birds, HY birds, and species richness were compared between the preharvest and postharvest periods. Preharvest and postharvest periods were May 1996 to May 1999 (n = 39) and June 1999 to August 2001 (n = 33), respectively, for total captures and species richness. Because HY birds were captured beginning in June, preharvest and postharvest periods were defined for HY birds as June 1996 to August 1998 (n = 27) and June 1999 to August 2001 (n = 27), respectively.

Recaptures were used to determine intra- and inter-stand movements, and a recaptured bird was defined as one that was recaptured during a subsequent day from the initial capture date. Seven species with ≥ 10 recaptures were used in the movement analysis because we felt species <10 recaptures would not accurately reflect a possible response to the harvest. Recaptured individuals were determined by the band number of the recaptured bird. Movements within and between stands and preharvest and postharvest periods were determined by recording the nets (based on a unique net number) where the initial and all subsequent captures were made. Multiple recaptures of the same individuals were used in the movement analysis (average number of recaptures = 1.97, n = 241 birds, SE = 0.09, range = 1-8). To detect immediate and direct effects of the harvest, a subset of recaptures (n = 49) was analyzed where birds were initially captured during the preharvest period and recaptured during the postharvest period.

Vegetative characteristics were sampled from 15 0.04-ha circular plots in each 10.6-ha stand. Circular plots were randomly selected and measured at intersection points of the 25-m by 25-m sampling grid in each stand. To ensure that the entire stand was sampled, one plot was randomly selected from each of the grid's 11 transects, and 4 plots were additionally randomly selected from the same 11 transects. Vegetation sampling was done July-August 1995 and August-September 1999 for the preharvest and postharvest measurements, respectively. Within the 0.04-ha plot, we measured diameters (cm) at 1.4 m height (dbh), heights (m), stem densities (number/ha), and basal areas (m^2/ha) of all live woody stems ≥12.7 cm dbh and ≥2 m tall. Shrub densities (# stems/ha) were determined from belt transects along the N-S and E-W transects where all live woody stems were counted that intersected a 1.0-m wide stick held 1.4 m above the ground.

The number of birds captured by mist-nets are influenced by precipitation (Silkey et al. 1999) so monthly precipitation (cm) totals from a weather station operated by the U.S. Forest Service in Foresthill, Placer County, CA (elevation = 916 m, 39°01'70"N, 120°85'00"W) were used to assess the effect of precipitation on bird captures. Precipitation data from a nearby station located in Georgetown, El Dorado County, CA (elevation = 914 m, 38°93'30"N, 120°80'00"W) were equivalent to the Foresthill data when the two data sets were compared so the Foresthill data were used because it was

the weather station closest to the study stand.

Normal probability plots, frequency histograms, and calculations of variance, skewness and kurtosis were used to assess normality and variance homogeneity of vegetation, weather, and banding data. Because most data did not meet assumptions and distribution requirements for parametric statistics, data were transformed (Stewart-Oaten et al. 1986, Zar 1996). Square root transformations [square root (value + 0.5)] were used for vegetation data (Zar 1996). Banding and precipitation data were transformed using log transformations [$\log_{10}$ (value + 1)] (Stewart-Oaten et al. 1986, Zar 1996).

Two-sample t-tests for unequal variances were used to determine differences in preharvest vegetation characteristics between the treatment and control stands, while paired t-tests were used to determine differences between pre- and postharvest vegetation characteristics in the treatment stand. Comparisons of capture differences between pre- and postharvest periods were done using a two-sample t-test for unequal variances (Stewart-Oaten et al. 1986 and 1992). The Durbin-Watson statistic (D) was calculated for banding captures during the preharvest period to evaluate the independence of the capture data between successive banding days.

Analysis of covariance with repeated measures was used to determine if bird captures and between-stand capture differences were affected by the fixed factors - stand (capture totals only) and treatment period (capture totals and capture differences) - when monthly precipitation totals for May, June, July, and August were used as a covariate to adjust capture totals for weather effects. The repeated measures were the number of birds captured and between-stand capture differences for the three banding days conducted each month. For HY birds, capture totals and between-stand capture differences and precipitation totals from June, July, and August were used as 1 of 196 (0.5%) HY birds were captured in May. Chi-square tests were used to determine if recaptured bird movements were independent of stand and treatment. Statistical analyses were conducted using SYSTAT (SPSS Incorporated 2000a and 2000b).

Following recommendations of The Wildlife Society (1995a and 1995b) and Steidl et al. (1997) we addressed the retrospective power and the biological and statistical significance of our results to evaluate the possibility of Type I (α) and Type II (β) errors. Statistical significance was $P<0.05$ for vegetation and banding data as well as relationships between precipitation and banding data. Power was determined for nonsignificant t-tests for the banding results only to assess the potential for committing a Type II error (e.g., falsely accepting the null hypothesis) (The Wildlife Society 1995a). Biological significance of banding results (effect size) was defined as a difference of $\geq$100% in total captures of all birds, HY birds, and species richness between stands between the pre- and postharvest periods.

RESULTS

Vegetation

The two stands had very similar vegetation conditions prior to harvesting and some differences after harvesting (Table 1). During the preharvest period, the treatment

stand had greater densities of hardwoods in the shrub layer ($P = 0.003$) while the control stand had greater densities of *Ceanothus* ($P = 0.005$). During the postharvest period, the control stand had larger average diameter stems of all trees and conifers ($P < 0.007$), shorter hardwoods ($P = 0.008$), greater basal area of all trees ($P = 0.047$), and lesser densities of hardwoods in the shrub layer ($P = 0.019$) than the treatment stand (Table 1). After harvesting in the treatment stand, stem densities of all trees and conifers were reduced by approximately 25% ($P < 0.007$), and basal area of all trees, hardwoods, and conifers were reduced by approximately 28% ($P < 0.041$) (Table 1). In the control stand, vegetation conditions were mostly very similar between the preharvest and postharvest periods except that average diameters of all stems increased ($P = 0.024$) by 10% and densities of conifers declined by 13% ($P = 0.027$).

Banding Effort

Nets were operated for 4717 hr in the treatment stand and 4726 hr in the control stand over the 6-year study period. Total net hours were equivalent between stands for all 6 years ($t = -0.294$; $df = 9.3$; $P = 0.775$). Over the 6-year period, net hours averaged 786 hr per year (SE = 4.0, n = 6) and 788 hr per year (SE = 3.0, n = 6) in the treatment and control stands, respectively. Over the 6-year period, net hours per banding day were equivalent between stands ($t = -0.191$; $df = 142.0$; $P = 0.849$) and averaged 65.5 hr (SE = 0.3, n = 6) and 65.6 hr (SE = 0.3, n = 6) in the treatment and control stands, respectively. In the treatment stand, net hours per banding day averaged 65.6 hr (SE = 0.8, n = 39) and 65.4 hr (SE = 0.3, n = 33) during the pre- and postharvest periods, respectively ($t = 0.221$; $df = 47.8$; $P = 0.826$). In the control stand, net hours per banding day averaged 65.5 hr (SE = 0.8, n = 39) and 65.8 hr (SE = 0.2, n = 33) during the pre- and postharvest periods, respectively ($t = -0.456$; $df = 41.8$; $P = 0.651$). Over the six-year assessment period, there were 39 and 33 banding days during the preharvest (May 1996 to May 1999) and postharvest (June 1999 to August 2001) periods, respectively.

Landbird Responses

Captures

Between 1996-2001, a total of 1070 birds of 32 species was captured (Table 2). Almost one-half of all birds captured were dark-eyed juncos (see Appendix A for scientific names of all birds) (n = 340, 31.8%) and black-headed grosbeaks (n = 186, 17.4%) (Table 2). A total of 196 HY birds were captured over the 6-year study period, predominantly dark-eyed juncos (n = 88, 44.9%), black-headed grosbeaks (n = 23, 11.7%), and Steller's jays (n = 23, 11.7%).

There were proportionately fewer total birds captured in the control stand than the treatment stand during the postharvest period ($X^2 = 14.33$; $df = 1$; $P < 0.001$) including dark-eyed juncos ($X^2 = 5.50$; $df = 1$; $P = 0.019$) and black-headed grosbeaks ($X^2 = 9.38$; $df = 1$; $P = 0.002$). There were also proportionately fewer HY birds captured in the control stand than the treatment stand during the postharvest period ($X^2 = 17.84$; $df = 1$; P

Table 2. Birds captured in two 10.6-ha stands during May-August 1996 to 2001 in Placer County, California. Group selection logging was done in June 1999 in the treatment stand (T) while no logging was done in the control stand (C).

Species[a]	Pattern[b]	1996		1997		1998		1999		2000		2001		Total
		C	T	C	T	C	T	C	T	C	T	C	T	
White-headed woodpecker[c]	R	0	0	0	0	1	0	0	0	0	1	0	0	2
Northern flicker	R	0	0	0	0	0	0	0	0	1	1	0	0	2
Red-breasted sapsucker	R	0	0	1	1	0	0	2	0	0	0	0	0	4
Downy woodpecker	R	0	0	1	0	1	0	0	0	3	1	0	1	7
Hairy woodpecker	R	0	0	2	1	3	1	0	2	0	0	0	0	9
Western wood-pewee	S	0	0	1	1	1	3	0	2	0	4	0	0	12
Hammond's flycatcher	S	1	3	0	0	0	1	0	0	0	0	0	1	6
Dusky flycatcher	S	0	2	0	0	1	0	0	0	0	1	0	0	4
Pacific-slope flycatcher	S	3	1	1	0	1	0	0	1	3	2	1	0	13
Cassin's vireo	S	4	5	0	3	2	3	4	1	0	2	0	4	28
Warbling vireo	S	1	1	0	0	1	0	0	0	0	2	0	0	5
Steller's jay	R	3	2	3	0	0	1	0	0	1	1	5	7	23
Mountain chickadee	R	0	1	0	0	1	1	0	0	0	1	0	2	6
Brown creeper	R	3	1	3	3	2	2	2	2	3	2	1	3	27
White-breasted nuthatch	R	0	1	0	0	0	0	0	0	0	0	1	0	2
Red-breasted nuthatch	R	2	1	0	0	0	1	0	0	3	6	0	0	13
Hermit thrush	M	0	0	0	0	0	1	1	2	0	0	0	2	6
American robin	R	3	6	11	8	10	18	8	3	5	11	7	9	99
Orange-crowned warbler	S	0	0	0	0	0	1	0	0	0	2	1	0	4
Nashville warbler	S	4	5	2	4	14	6	7	1	7	6	3	3	62
Yellow-rumped warbler	S	3	5	2	4	6	2	3	4	2	1	0	2	34
Black-throated gray warbler	S	0	1	0	0	0	0	0	0	0	6	0	2	9
Hermit warbler	S	1	0	0	0	0	0	0	0	0	0	0	0	1

Species[a]	Pattern[b]	1996 C	1996 T	1997 C	1997 T	1998 C	1998 T	1999 C	1999 T	2000 C	2000 T	2001 C	2001 T	Total
MacGillivray's warbler	M	1	0	0	0	3	0	1	0	1	1	0	0	7
Wilson's warbler	M	0	0	0	1	2	0	0	0	1	0	0	0	4
Western tanager	S	2	9	1	7	2	8	3	4	2	10	2	6	56
Spotted towhee	R	8	7	5	10	9	10	10	6	7	5	4	8	89
Chipping sparrow	S	0	0	0	1	0	4	0	0	0	0	0	0	5
Dark-eyed junco	R	30	34	28	34	26	39	18	28	13	41	14	35	340
Black-headed grosbeak	S	17	14	20	13	14	20	8	14	11	23	10	22	186
Lazuli bunting	S	0	1	0	0	0	0	0	0	1	0	0	0	2
Purple finch	S	1	1	0	0	0	0	0	0	0	1	0	0	3
	Total	87	101	81	91	100	122	67	70	64	131	49	107	1070

[a] The following seven species were only caught once and are not included in the table - brown-headed cowbird (S), bushtit (R), chestnut-backed chickadee (R), Hutton's vireo (R), ruby-crowned kinglet (W), unidentified yellow-rumped warbler (S), and golden-crowned sparrow (W).
[b] Seasonality patterns based on Small (1994): R = yearlong breeding resident; S = summer breeding resident; M = nonbreeding spring and fall migrant; W = nonbreeding winter visitor.
[c] Scientific names in Appendix A.

<0.001). With dark-eyed juncos proportionately more HY birds were captured in the control stand during the preharvest period while more HY birds were captured in the treatment stand during the postharvest period (X^2 = 12.99; df = 1; P <0.001).

Pairwise differences between the treatment and control stands were greater for the postharvest period than the preharvest period for total captures of all species (t = -4.04; df = 69.5; P <0.001), total captures of HY birds (t = -2.87; df = 51.9; P = 0.006), and total number of species captured (t = -2.74; df = 68.2; P = 0.008) (Figure 1, Table 3). It was unnecessary to assess statistical power for these three tests because they were all statistically significant (P <0.008). These differences for the postharvest period were biologically significant because they were greater than the 100% difference threshold from the preharvest period and because the 95% confidence intervals for average pairwise differences for the postharvest period were >0.0 (Table 3). Durbin-Watson statistics from the preharvest period for differences in total captures (d = 1.73) and HY birds (d = 2.09) indicated that differences in capture totals from successive banding days were not autocorrelated. The Durbin-Watson statistic, however, from the preharvest period for differences in the total number of species captured (d = 1.45) indicated autocorrelation existed because positive differences tended to follow positive differences and negative differences tended to follow negative differences.

Movements

Frequencies of movements of banded birds between the treatment and control stands were equivalent between the preharvest and postharvest periods for the 7 species with ≥ 10 recaptures (X^2 = 0.33-7.04; df = 3; P >0.071) (Table 4). The total number of combined movements for these seven species were also equivalent between stands and treatment periods (X^2 = 2.87; df = 3; P = 0.413). A total of 49 birds of 8 species was banded prior to harvest and recaptured after harvesting, allowing us to determine if the treatment induced bird movements. Twenty-six of these 49 birds were captured and recaptured in the treatment stand, and 18 birds were captured and recaptured in the control stand. Three birds of these 49 birds were captured in the treatment stand and recaptured in the control stand, and the remaining 2 birds were captured in the control stand and recaptured in the treatment stand. These frequency patterns demonstrated there was little between-stand movement of birds due to the group selection harvest (X^2 = 27.05; df = 1; P <0.001).

Weather Effects

Stand and treatment factors did not significantly (P >0.141) affect captures of the total number of birds, HY birds, and number of species when capture totals were adjusted for May-August monthly precipitation totals (Table 5). Greater numbers of birds and species were captured during months with greater precipitation (P <0.001) (Table 5). Differences occurred (P <0.009) in the repeated measure of the number of species captured during the three capture days within each month. Significant statistical interaction (P <0.013) occurred between banding day and precipitation for total captures and number of species captured (Table 5) as more birds and species were

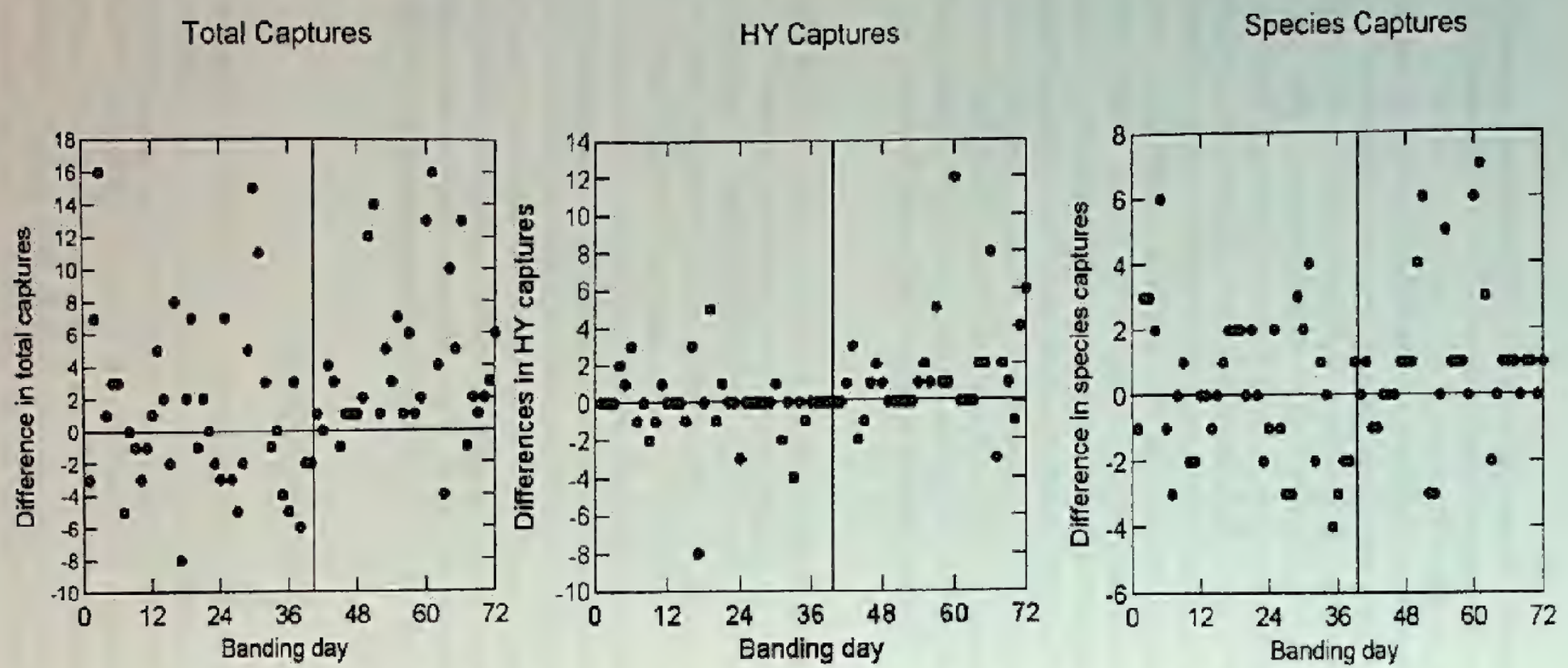

Figure 1. Differences in captures of all birds (total captures), young of the year (HY captures), and species between the treatment and control stands by banding day. Vertical lines separate banding days between the preharvest (banding day 1-39) and postharvest (banding day 40-72) periods. Horizontal lines indicate no difference between the treatment and control stands; points above and below the horizontal line indicate more captures in the treatment and control stands, respectively. Greater differences occurred between the treatment and control stands in the postharvest period for all three measures (two-sample t-tests, $P < 0.008$).

Table 3. Statistics for biologically significant differences in birds captured at two 10.6-ha stands during May-August 1996 to 2001 in Placer County, California. Group selection logging was done in June 1999 in the treatment stand (T) while no logging was done in the control stand (C). May 1996-May 1999 and June 1999-August 2001 are the preharvest and postharvest periods, respectively.

Period and statistic	Total captures	HY captures	Species captures
Preharvest			
average	1.13 (n = 39)	-0.22 (n = 27)	0.10 (n = 39)
95 percent lower CI[a]	-0.62	-1.18	-0.63
95 percent upper CI	2.88	0.73	0.83
Range for ±100 percent biologically significant values	0.00 to 2.26	- 0.44 to 0.00	0.00 to 0.20
Postharvest			
average	4.00 (n = 33)	1.82 (n = 27)	1.03 (n = 33)
95 percent lower CI	2.25	0.59	0.21
95 percent upper CI	5.75	3.04	1.86
Percent difference[b]	254	927	930

[a] CI - Confidence interval
[b] Percent difference = [(Postharvest ave. - Preharvest ave.)/Preharvest ave.]*100

captured for the three banding days during months with greater precipitation. Significant statistical interaction (P <0.045) occurred between stands and treatment period as greater and lesser numbers of HY birds were captured in the treatment and control stands, respectively, during the postharvest period (Table 5).

When adjusted for precipitation, greater pairwise differences were found for the total number of birds and HY birds captured during the postharvest period (P <0.041) and precipitation did not affect these pairwise differences (P >0.485) (Table 5). Pairwise differences between treatment periods in captures of the number of species were almost significantly different (P =0.061) when adjusted for monthly precipitation, and precipitation did not influence (P =0.859) these differences. Repeated measures of pairwise capture differences were equivalent (P >0.544) within each month and treatment period.

Over the 6-year study period, an average of 95.5 percent of the May-August precipitation resulted from precipitation in May and June, while 72.9 percent of all birds (n = 780) were caught in May and June so most precipitation and most bird captures occurred during the first half of the spring-summer study period. Captures of all birds were significantly different between stands (F = 9.29; df = 1, 19; P = 0.007) but not treatment period (F = 0.23; df = 1, 19; P = 0.635) when adjusted for May-June precipitation (F = 0.58; df = 1, 19; P = 0.455). There were no differences in the number of species between stands (F = 2.70; df = 1, 19; P = 0.117) and treatment periods (F =

Table 4. Movements of recaptured birds between a 10.6-ha treatment stand and a 10.6-ha control stand between a preharvest period (May 1996 - May 1999) and a postharvest period (June 1999 - August 2001) in Placer County, California.

Species	Stand Movement Combinations: Treatment to Treatment	Treatment to Control	Control to Control	Control to Treatment	X^2 *P*-values (df = 3)
American robin[a]					
Preharvest	2	3	10	2	0.521
Postharvest	1	2	3	3	
Black-headed grosbeak					
Preharvest	7	4	14	3	0.071
Postharvest	18	2	10	1	
Dark-eyed junco					
Preharvest	78	3	50	3	0.851
Postharvest	45	2	25	3	
Nashville warbler					
Preharvest	1	0	4	0	0.572
Postharvest	3	1	1	0	
Spotted towhee					
Preharvest	7	1	9	0	0.713
Postharvest	10	0	9	0	
Western tanager					
Preharvest	5	1	0	0	0.711
Postharvest	4	2	0	1	
Yellow-rumped warbler					
Preharvest	1	0	3	1	0.954
Postharvest	2	0	3	0	
All species					
Preharvest	101	12	90	9	0.413
Postharvest	83	9	51	8	

[a] Scientific names of all species are in Appendix A.

0.55; df = 1, 19; $P = 0.468$) when adjusted for May-June precipitation. In addition, pairwise differences between treatment periods were not significant when adjusted for May-June precipitation for total captures ($F = 4.51$; df = 1, 9; $P = 0.063$) and number of species captured ($F = 0.39$; df = 1, 9; $P = 0.547$). Similar analyses were not possible with HY birds because total HY bird captures and pairwise differences in HY bird captures were approximately equal in June, July, and August while precipitation patterns were not.

Table 5. Repeated measures analysis of covariance results with stand and treatment as fixed factors and total monthly precipitation (cm) (May-August for total birds and species; June-August for HY birds) as the covariate on the number of birds captured and capture differences between 1996-2001 at paired treatment and control 10.6-ha study stands in Placer County, California.

	Total Birds Captured				HY Birds Captured				Number of Species Captured			
Captures	SS	df	F	P-value	SS	df	F	P-value	SS	df	F	P-value
Between Subjects												
Stand	0.40	1	2.26	0.141	0.20	1	1.94	0.173	0.11	1	1.15	0.289
Treatment	0.02	1	0.12	0.733	0.08	1	0.81	0.376	0.01	1	0.10	0.751
Stand x Treatment	0.61	1	3.47	0.069	0.44	1	4.37	0.045	0.17	1	1.80	0.187
Precipitation	2.81	1	16.01	0.001	0.03	1	0.27	0.610	1.21	1	13.04	0.001
Error	7.54	43			3.12	31			4.00	43		
Within Subjects												
Replicate	0.13	2	1.25	0.292	0.07	2	0.51	0.601	0.30	2	4.97	0.009
Replicate x Stand	0.02	2	0.21	0.813	0.07	2	0.50	0.608	0.04	2	0.59	0.555
Replicate x Treatment	0.07	2	0.69	0.505	0.29	2	2.14	0.126	0.01	2	0.16	0 850
Replicate x Stand x Treatment	0.01	2	0.04	0.957	0.29	2	2.18	0.122	0.01	2	0.15	0.864
Replicate x Precipitation	0.49	2	4.57	0.013	0.31	2	2.33	0.105	0.33	2	5.46	0.006
Error	4.58	86			4.14	62			2.60	86		
Differences in Captures	SS	df	F	P-value	SS	df	F	P-value	SS	df	F	P-value
Between Subjects												
Treatment	1.23	1	14.14	0.001	0.72	1	5.00	0.041	0.25	1	3.93	0.061
Precipitation	0.04	1	0.51	0.485	0.03	1	0.18	0.680	0.00	1	0.03	0.859
Error	1.82	21			2.15	15			1.35	21		
Within Subjects												
Replicate	0.04	2	0.34	0.712	0.12	2	0.62	0.544	0.03	2	0.40	0.676
Replicate x Treatment	0.02	2	0.13	0.877	0.43	2	2.22	0.126	0.01	2	0.18	0.890
Replicate x Precipitation	0.02	2	0.18	0.837	0.27	2	1.35	0.274	0.03	2	0.38	0.687
Error	2.40	42			2.93	30			1.68	42		

DISCUSSION

We could not conclude that the group selection harvest had significant and consistent adverse effects to the landbird community present during the breeding season during the 3-year postharvest period in the two stands studied. We observed a positive effect as more birds were captured in the treatment stand during the postharvest period. Fewer birds, however, were captured in the control stand during the same postharvest period. There was also a marked decline in the number of birds captured in the control and treatment stands the same year harvesting occurred, so an immediate treatment effect probably occurred to birds in both stands. This was a short-term impact as bird populations were considerably greater in the treatment stand for the last 2 years of postharvest monitoring. Population responses by other bird communities to treatments like group selection harvesting that partially remove vegetation have varied (Vega and Rappole 1994, Kilgo et al. 1999).

The dark-eyed junco and black-headed grosbeak were the most frequently captured species, so their population responses primarily determined the outcome of this study. Both species are widespread and common in montane hardwood-conifer habitats in the central Sierra Nevada (Beedy and Granholm 1985, Small 1994), and captures of these two species increased in the treatment stand during the postharvest period, indicating a favorable response to the group selection harvest. Reproduction by dark-eyed junco appears to have increased with the group selection harvest as there were more postharvest captures of HY birds in the treatment stand. Between-stand movements by seven species did not change with group selection logging, indicating that we were unable to detect any immediate behavioral impacts. In addition, minimal and equivalent between-stand movements indicates that bird responses were likely due to actual changes in their populations.

Differences in captures in the two stands caused the statistically significant pairwise differences between the pre- and postharvest periods. Comparing differences between treatment and control stands between pre- and post-impact periods using the BACIP design as we did is a powerful method to assess environmental impacts (Stewart-Oaten et al. 1986 and 1992; Wiens and Parker 1995; Steidl et al. 1997) so we are confident these represent biologically significant differences especially given the lack of influence by precipitation. In fact, pairwise differences in total captures, HY captures, and number of species captured were biologically significant as they exceeded the 100% difference threshold and the 95% confidence intervals did not include 0.0. Using confidence intervals and investigator-specified thresholds for biological significance are necessary so that managers can more thoroughly assess the effect of management actions on wildlife populations instead of relying solely on statistical significance testing which has the potential for Type I and Type II errors (The Wildlife Society 1995a and 1995b, Steidl et al. 1997).

Numbers of birds captured varied with monthly precipitation, and both stand and treatment factors were not significant when numbers of captures were adjusted for monthly precipitation. Between-stand capture differences for all birds and HY birds, however, remained significant when adjusted for monthly precipitation so precipitation

differentially affected the two types of response variables (capture numbers and between-stand capture differences). Most precipitation occurred in May and June, the same period when most birds were captured. Bird captures declined in July and August when precipitation also declined. More birds were also captured during years with more precipitation in May and June.

A bird population pattern, based on mist-net captures, tracking monthly precipitation existed in these stands. Mist-net capture rates have been shown to be linearly related to annual precipitation for birds in California's coastal scrub habitats, although the biological mechanism is unknown (Silkey et al. 1999). Precipitation affects vegetation which in turn affects avian behavior (Silkey et al. 1999) and precipitation clearly influences many levels of avian biological processes (Rotenberry and Wiens 1991). There are variable effects of precipitation on bird populations because population levels and productivity varies with changing precipitation (Rotenberry and Wiens 1991, Verner and Purcell 1999). The bird community in our stands consists of yearlong residents, short-distance migrants, and long-distance neotropical migrants so individual species responses to precipitation are likely operating (Hejl et al. 1988).

The group selection harvest removed approximately one-fourth of the basal area and number of trees and affected approximately one-fourth of the ground area in a 10.6-ha treatment stand. These changes occurred at a relatively small scale so birds had enough unharvested habitat within and adjacent to the treatment stand to persist after the harvest. Very little vegetation existed in the individual harvest units the first breeding season after harvesting, and harvesting occurred during the mid-point of the first postharvest breeding season so some birds, particularly yearlong residents like American robins, spotted towhees, and dark-eyed juncos had already started breeding when the harvesting occurred. Once the vegetation began growing back after harvest, habitat conditions improved such that populations increased. We are unsure why bird populations declined in the unharvested control stand during the postharvest period where habitat conditions were essentially unchanged. Harvest-caused habitat changes in the treatment stand interacting with monthly precipitation may have increased bird populations in the treatment stand, while precipitation may not have had equivalent effects on bird populations in the control stand where that interaction may not have been as pronounced. Habitat and weather interactions affecting bird populations at the stand level of our study have occurred as Hejl et al. (1988) showed for birds in Sierra Nevada fir forests and as Franklin et al. (2000) and North et al. (2000) demonstrated for spotted owl, *Strix occidentalis*, populations over much larger areas than our study encompassed. Habitat and weather can increase or decrease in importance in their effects on populations depending on changes in each factor (Holmes 1995). Furthermore, the mechanisms by which bird populations response to forest management are very complex and difficult to study (Marzluff et al. 2000) so the variable responses by birds we studied are not surprising.

Using banding data to monitor bird populations has been questioned (Remsen and Good 1996), although it has been shown that banding results do track population trends as measured by more traditional bird population monitoring techniques such as spot-

mapping (Silkey et al. 1999). Preliminary analyses of point count data from the same period from these two stands plus three more replicated stands in the same area indicates similarly variable, including positive and negative, responses by landbirds (unpublished data). We believe, however, that the results from bird banding are more reliable than point counts because of the controlled nature and consistency of the banding effort. Our results should be cautiously interpreted when extrapolating to group selection harvests throughout the central Sierra Nevada and in different habitats for these reasons as well as the short study period and lack of stand replication. The 6-year period of study does, however, far exceed that for the majority of previous studies assessing effects of timber harvesting on bird populations (Sallabanks et al. 2000). As trees and shrubs become reestablished in the group selection harvest units over time, bird populations should respond to varying degrees. The amount of precipitation, however, will continue to variously influence landbird populations present during the breeding season, and precipitation should be recognized by land managers as an influence on landbirds and their responses to timber harvest activities in the central Sierra Nevada.

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Appendix A. Scientific names of birds mentioned in text and tables.

Common name	Scientific name
White-headed woodpecker	*Picoides albolarvatus*
Northern flicker	*Colaptes auratus*
Red-breasted sapsucker	*Sphyrapicus rubus*
Downy woodpecker	*Picoides pubescens*
Hairy woodpecker	*Picoides villosus*
Western wood-pewee	*Contopus sordidulus*
Hammond's flycatcher	*Empidonax hammondii*
Dusky flycatcher	*Empidonax oberholseri*
Pacific-slope flycatcher	*Empidonax difficilis*
Hutton's vireo	*Vireo huttoni*
Cassin's vireo	*Vireo cassinii*
Warbling vireo	*Vireo gilvus*
Steller's jay	*Cyanocitta stelleri*
Mountain chickadee	*Poecile gambeli*
Chestnut-backed chickadee	*Poecile rufescens*
Bushtit	*Psaltriparus minimus*
Brown creeper	*Certhia americana*
White-breasted nuthatch	*Sitta carolinensis*
Red-breasted nuthatch	*Sitta canadensis*
Ruby-crowned kinglet	*Regulus calendula*
Hermit thrush	*Catharus guttatus*
American robin	*Turdus migratorius*
Orange-crowned warbler	*Vermivora celata*
Nashville warbler	*Vermivora ruficapilla*
Yellow-rumped warbler	*Dendroica coronata*
Unidentified yellow-rumped warbler	*Dendroica* sp.
Black-throated gray warbler	*Dendroica nigrescens*
Hermit warbler	*Dendroica occidentalis*
MacGillivray's warbler	*Oporonis tolmiei*
Wilson's warbler	*Wilsonia pusilla*
Western tanager	*Piranga ludoviciana*
Spotted towhee	*Pipilo maculatus*
Chipping sparrow	*Spizella passerina*
Golden-crowned sparrow	*Zonotrichia atricapilla*
Dark-eyed junco	*Junco hyemalis*
Black-headed grosbeak	*Pheucticus melanocephalus*
Lazuli bunting	*Passerina amoena*
Brown-headed cowbird	*Molothrus ater*
Purple finch	*Carpodacus purpureus*

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ENVIRONMENTAL VARIABLES ASSOCIATED WITH A CHINOOK SALMON REDD IN DEER CREEK, CALIFORNIA

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We studied the ecology of a chinook salmon, *Oncorhynchus tshawytscha*, redd in Deer Creek, a tributary of the Sacramento River. Dissolved oxygen (D.O.) concentrations were generally >10 mg/L. In March, however, D.O. concentrations dropped to approximately 5 mg/L 30 and 46 cm deep within the gravels. Trace elements were also higher in March in the deep gravels. Midges (Chironomidae) and aquatic worms (Naididae) were strongly associated with dead eggs and fungus that were 30 cm deep in the gravels. We recovered no alevins from capping this redd. Sediment deposited on top of the redd during a winter storm, elevated trace elements, and low D.O. may have resulted in egg/alevin mortality.

INTRODUCTION

The decline in abundance of chinook salmon, *Oncorhynchus tshawytscha,* in California has been well documented (Yoshiyama et al. 1998). The incubation stage is considered a critical period in chinook salmon life history (Gangmark and Bakkala 1960), with survival of salmon eggs to fry emergence highly variable. Reported values range from 3% of eggs failing to hatch in chinook salmon redds with good percolation rates (Shelton 1955, Vronskiy 1972) to 68-93% mortality at redds in Fall Creek, CA (Wales and Coots 1954). Factors influencing egg survival need to be understood to aid in recovery of federally listed anadromous salmonids. Spawning activity in freshwater streams and rivers results in the burial of eggs in the substrate, typically to a depth of approximately 30 cm (e.g., DeVries 1997). Water quality at this depth (interface between surface water and groundwater, in the hyporheic zone) may be very different from that found at the surface (Soulsby et al. 2001). Furthermore, water quality in the hyporheic zone may be important in the selection of spawning sites (Geist 2000). Hyporheic biotic conditions that may be important to egg success include invertebrate composition and biomass, and investigators have suggested that studies of hyporheic zone utilization by invertebrates associated with salmon spawning runs are needed (Peterson and Foote 2000). Little information is available on hyporheic zone ecology relative to egg survival in salmon redds.

This paper describes information from monitoring environmental variables associated with a fall-run chinook salmon redd in Deer Creek, Tehama County, California. This single redd was approximately 400 m downstream from the Highway 99 bridge along the north bank of Deer Creek. In the autumn and winter of 1999-2000 we measured abiotic and biotic variables in surface water and hyporheic water immediately adjacent to the

redd. Fry emergence was monitored by capping the redd.

METHODS

We observed an individual female fall-chinook salmon digging and then spawning with accompanying males from 10 November 1999 through 12 November 1999. Postspawning, the redd was fenced to ensure no additional spawning occurred over the redd. In December, after the spawning season ended, the fence was removed and a redd cap frame for holding netting was placed over the redd. Netting was placed on the frame on 7 March 2000 so that salmon fry that emerged in March could be counted. Temperature unit analysis with hyporheic temperature data indicated that emergence would occur in mid-March. After the netting was installed, daily checks of the redd cap took place and fish were removed, identified, and released.

We installed hyporheic pot samplers immediately adjacent to the redd on 13 November 1999. Hyporheic pot samplers were built of polyvinyl chloride (PVC) pipe 10 cm in diameter and 46 cm long (similar to Figure 2 in Nelson and Roline, 1999). Approximately 20% of the sampler surface area was perforated with 2 cm diameter holes. A foam insert was placed at the -10 cm level to separate surface from deeper samples. At the -30 cm level a PVC slip fitting allowed for connection to the -30 to -46 cm portion of the sample. These two portions of the sampler were connected with cable ties so that when the sampler was removed, the ties could be cut and portions of the sampler processed separately. Samplers were installed vertically into the substrate. Excavations, in which the samplers were installed, were made in the stream bed using hand trowels. Substrate used in the samplers was from the hole in which the sampler was installed. Two samplers were placed immediately adjacent to the salmon redd. A fused glass airstone was attached at the bottom and at the -30 cm level of each hyporheic sampler. Plastic tubing, connected to airstones, led to the surface to allow for collection of water samples from these deeper substrates. An incubation cage (3 cm high, 9 cm diameter) built of 64-mm mesh polypropylene material which contained 20 salmon eggs obtained from the Coleman Fish Hatchery was also placed in the hyporheic pot at the -30 cm level. Hatchery eggs were spawned from a single female, transported in a cooler, and transferred to the Deer Creek site within 2 hours after fertilization. Piper et al. (1983) consider recently fertilized eggs as one developmental stage at which eggs can be shipped and handled, although higher losses may occur at this stage than would in the eyed egg stage. While survival of these eggs was considered desirable, the main purpose of these eggs was to mimic the redd environment within the hyporheic pot and as "bait" to attract a macroinvertebrate assemblage that would be associated with salmon eggs.

Contents of individual samples from retrieved hyporheic pots were placed into separate containers and macroinvertebrates preserved in formalin. In the laboratory, samples were washed in a 150-μm mesh screen sieve to remove formalin, organisms were picked from the substrate under 10X magnification, and invertebrates identified to lowest practical taxon using a binocular dissecting scope with continuous zoom from

10X to 70X.

Particle sizes of substrate were measured by drying the sample, passing it through a series of stacked sieves, and weighing the contents of each sieve. Samples from hyporheic pot samplers were sifted through 11 sieves ranging in mesh size from 75.0 to 0.062 mm. At the end of the study, we also sampled substrate in the redd by removing the material within a bottomless bucket (26 cm in diameter) placed on the redd center and inserted into the substrate as material was removed. Suspended fine sediment was collected using a 150-μm mesh screen. Size ranges of the 16 sieves used for this substrate sample ranged from 100 to 0.063 mm. Percent fines, particles smaller than 2.0 mm and 1.0 mm diameter (sand and smaller particles), were determined from these samples. Similar size-classes of fine particles have been shown to negatively affect salmonid egg survival in redds (e.g., Reiser and White 1988, Kondolf 2000).

Information on stream discharge was obtained from a USGS web site (http://water.usgs.gov). Piezometers were installed to a substrate depth of 46 cm at the front (in the pit) and rear (immediately posterior to the tailspill) of the redd after spawning was completed. The difference between water height in salmon redd piezometers and ambient stream water surface was measured using an e-tape. Piezometer data is presented as vertical hydraulic gradient (VHG) where the difference in water heights is divided by the distance that the piezometer is driven into the substrate. Positive readings suggest hyporheic discharge or upwelling, where hyporheic water enters the stream channel. Negative values indicate downwelling or recharge from the stream channel into the hyporheic zone.

A multiparameter meter was used to measure dissolved oxygen (D.O.), pH, temperature, and conductivity in surface and hyporheic water samples. Alkalinity and hardness were measured by titration within 24 hrs of sample collection. Inductively coupled plasma/emission spectroscopy was used for laboratory analyses of trace elements in water samples (EPA 1983, APHA 1989). Water samples used for metals analyses were filtered (0.45 micron filter) and preserved with 1 ml of nitric acid.

The IQ Toxicity Test™ was used to test water samples for toxicity in March 2000. The test was performed with 1-day-old *Daphnia magna* using methods similar to those presented in Janssen et al. (1993). Daphnids were exposed to triplicate toxicant dilutions for 2 hours, when an enzyme substrate (4-methylumbelliferyl-B-D-galactoside) was added for ingestion by the animals. After 15 minutes incubation, organisms were exposed to ultraviolet (U.V.) light and number of fluorescent daphnids counted. Cleavage or splitting of the substrate results in fluorescence under U.V. light and suggests that the animal is unaffected.

RESULTS

Although fall-run chinook salmon typically start spawning in September in Deer Creek, we did not observe any fish or evidence of spawning activity during a week-long trip in October. During a return trip in mid-November, fish were not observed for the first part of the week, but then a single female and accompanying males were observed on 10 November 1999. This female was approximately 77 cm in total length. Spawning

by this female was completed by 12 November 1999.

Greatest differences in water chemistry at different levels in samplers adjacent to the redd were observed on March 21st (Tables 1 and 2). Low D.O. (Table 1) and elevated trace element concentrations (Table 2) were observed in the deeper portions of the pot sampler. No acute toxicity was observed during the March 2000 sampling period. Samples in January and February were unobtainable because of high water (Figure 1).

Hyporheic pots were removed from the stream bed on 14 December 1999 and 21 March 2000. During the removal of the initial pot, the top portion was lost, therefore, only data from the egg basket and -30 to -46 cm portion of the pot was retained. A single egg, out of the 20 placed in the pot, appeared viable on 14 December 1999, 1 month after planting, while there were no viable eggs in the pot removed on 21 March 2000. Dead eggs were opaque and typically covered with fungus. The high mortality of these eggs may have been due to handling and transportation of eggs. Gangmark and Broad (1955) found that only 47.4% of chinook salmon eggs survived for 48 hours after using handling procedures and transportation times similar to ours.

Invertebrate data from samples is presented in Table 3. Sample volumes from the different hyporheic pot levels differed, therefore, for purposes of comparison, they were all converted to the standard unit of 1 m^3. *Chimarra*, *Chelifera*, and *Hyalella* were found at levels closest to the surface, while *Hydra* was only found in the deepest portions of the hyporheic pots. Midges were found throughout the pot, but some, like Chironomini and Orthocladiinae, were at highest densities in egg baskets at the -30 cm level. Naididae worms were also more abundant in the egg basket than at other levels. Overall invertebrate abundance was highest in the egg baskets, suggesting that salmon eggs or the fungus growing on them were an important food source for invertebrates in this Deer Creek salmon redd.

Table 1. Observations of water chemistry in surface waters and at two depths in the hyporheic zone (-30 cm and -46 cm) immediately adjacent to a fall-run chinook salmon redd in lower Deer Creek (Tehama County, CA). Spawning took place on 11 November 1999 and 12 November 1999.

Date	Level	Temperature (°C)	D.O. (mg/L)	pH (S.U.)	Cond. (μS/cm)	Alkalinity (mg/L)	Hardness (mg/L)
11-13-99	Surface	10.6	10.6	7.93	149	65	56
	-30 cm	10.8	10.2	7.90	150	66	51
	-46 cm	11.0	10.2	7.93	150	63	43
12-14-99	Surface	5.1	13.3	7.99	149	62	64
	-30 cm	5.2	13.0	7.97	150	60	60
	-46 cm	5.3	12.6	7.93	151	62	62
3-21-00	Surface	7.9	12.1	7.88	88	29	33
	-30	8.9	4.8	7.48	90	36	32
	-46	8.7	5.5	7.72	111	--	--

Table 2. Dissolved elements detected by ICP/ES (μg/L) in surface waters and at two depths in the hyporheic zone (-30 and -46 cm) immediately adjacent to a fall-run chinook salmon redd in lower Deer Creek (Tehama County, CA). Elements that were not detected and their detection limits are presented below*. Spawning took place on 11 November 1999 and 12 November 1999.

Element	14 December 1999			21 March 2000		
	Surface	-30 cm	-46 cm	Surface	-30 cm	-46 cm
Boron	123	123	123	39.4	34.4	43.4
Barium	12.9	12.8	12.1	7.44	7.25	9.85
Iron	18.9	15.4	12.0	16.0	7.44	33.3
Manganese	<4	<4	<4	<4	<4	32.1
Nickel	<10	<10	<10	<10	<10	14.7
Selenium	<30	<30	<30	<30	<30	37.2
Strontium	75.5	74.8	74.3	49.3	48.2	53.5
Vanadium	5.80	4.26	<4	<4	<4	6.61
Zinc	<4	<4	<4	<4	<4	5.68

*Silver<4, Aluminum<30, Arsenic<70, Berylium<0.5, Cadmium<4, Cobalt<3, Chromium<4, Copper<4, Lithium<6, Molybdenum<10, Lead<30, Antimony<20.

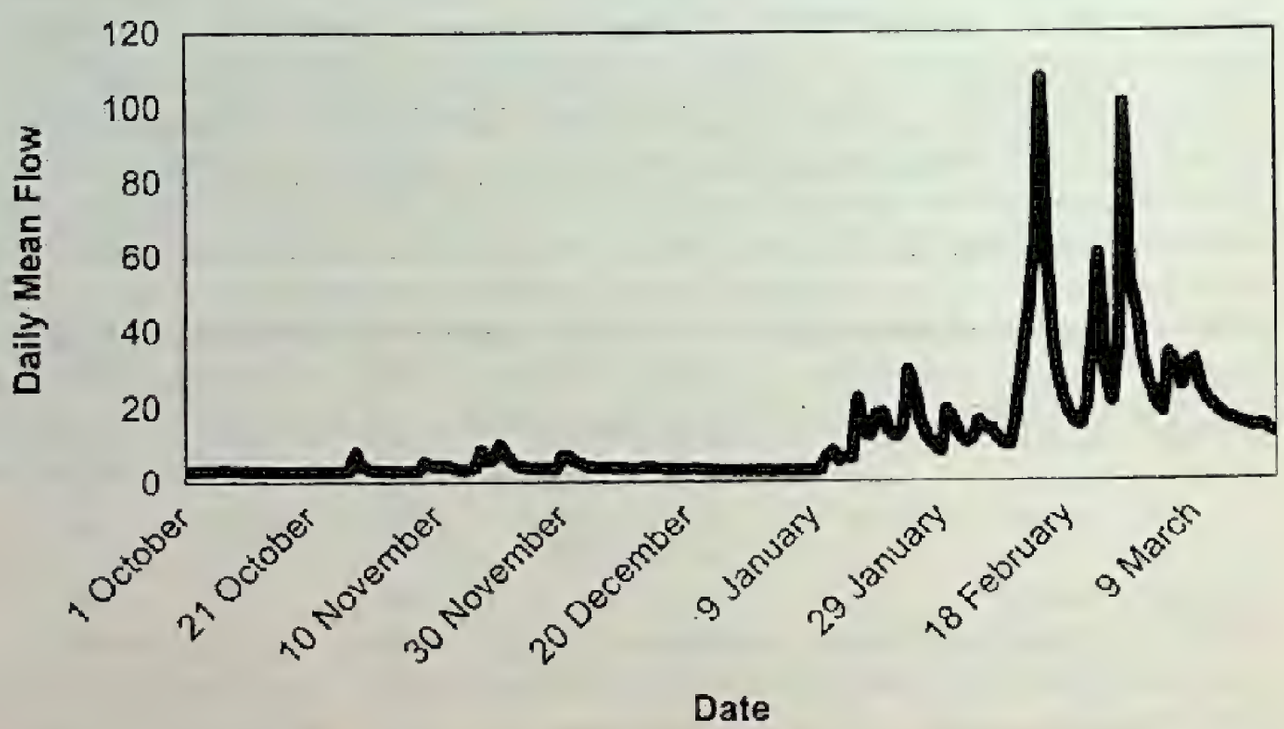

Figure 1. Daily mean streamflow (m^3/second) in Deer Creek, California during the period of study 1999-2000.

Table 3. Invertebrate data from hyporheic pots (number per m^3). Levels in hyporheic pots are indicated as centimeters from surface. The egg basket was located at the -27 to -30 cm level.

Taxa	14 December 1999			21 March 2000		
	-27 to -30 cm egg basket	-30 to -47 cm	0 to -10 cm surface	-10 to -27 cm	-27 to -30 cm egg basket	-30 to -47 cm
Ephemerella (early instar)	5240	0	0	0	0	0
Chimarra	0	0	1273	749	0	0
Lepidostoma	0	796	0	0	0	0
Chelifera	0	0	2546	0	0	0
Tanypodinae	0	0	1273	0	0	1592
Chironomini	15719	0	17825	5242	351057	31831
Orthocladiinae	5240	0	1273	749	26198	1592
Hydra	0	796	0	0	0	3979
Turbellaria	0	796	11459	0	5240	6366
Lumbriculidae	0	0	2546	1498	0	1592
Naididae	26198	7162	14006	5243	47157	16711
Ostracoda	5240	5570	1273	0	0	0
Hyalella	0	0	1273	0	0	0
Sphaeriidae	796	796	1273	0	0	0
Physidae	0	0	1273	749	15719	2387
Planorbidae	0	0	1273	0	5240	0
Total number (m^3)	58433	15916	58566	14230	450611	66050

Substrates in hyporheic pots (n=3) averaged 15.8% for particles with diameters < 2.0 mm and 10.7% for particles <1.0 mm. All of the substrate from hyporheic pots was <75.0 mm in diameter. Bulk sampling from the redd resulted in 11.8% of particles being <2.0 mm and 7.5% <1.0 mm. A small portion (11%) of this material was larger than 100 mm diameter. Winter rains caused flooding (Figure 1) which carried large amounts of material into the area and covered the redd with more than 15 cm of gravel and fine sediments. We installed a second redd cap frame and placed netting on top of the newly deposited substrate in early March. Daily discharge data (Figure 1) showed several floods occurred in winter 2000. These high flow events were reflected in mean monthly stream flows. For example, monthly streamflow statistics (http://water.usgs.gov) showed that the monthly mean streamflow in February 2000 was the 13th highest for the 85-year period of record and was approximately 1.8 times greater than the average flow for February. Vertical hydraulic gradient data obtained from piezometers indicated that upwelling occurred during most sampling occasions (Figure 2). The single exception was during sampling on 7 March 2000.

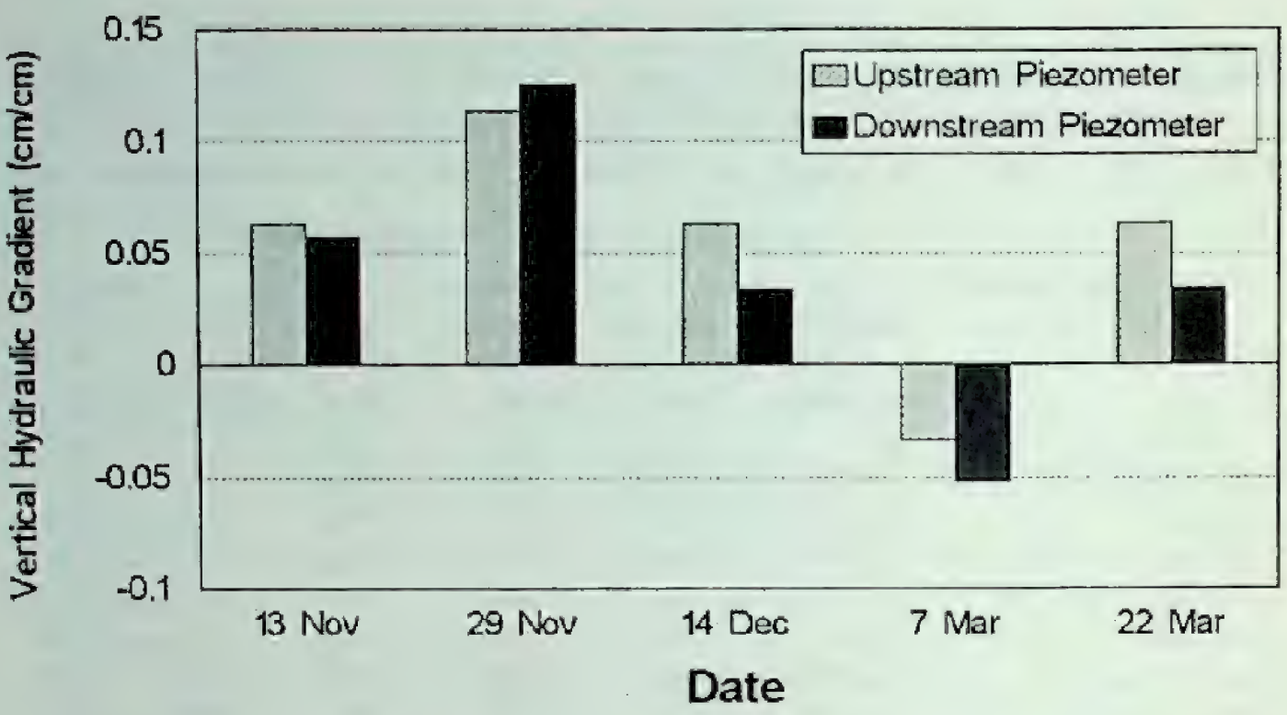

Figure 2. Vertical hydraulic gradient measured with piezometers placed immediately upstream and downstream of the tailspill of a fall -chinook salmon redd in autumn 1999 and winter 2000.

Thermal unit analysis with hyporheic temperature data suggested that fry emergence would occur after 7 March. Daily checks in March found no salmon fry captured from the redd cap.

DISCUSSION

The absence of emerging larval salmon from the redd suggests that survival within the redd was poor or nonexistent. Collected data provides several possible reasons for low survival. Percent sand and fines were at levels that approached the threshold for salmonid incubation effects of 12-14% of particles finer than 1 mm diameter (Kondolf 2000). Little information is available that is specific to chinook salmon egg survival as it relates to redd particle size. Reiser and White (1988) found that 10% fines (<0.84 mm diameter) resulted in large decreases in chinook egg survival (using green eggs) in a matrix of substrate ranging from 12.8 to 76.2 mm in diameter. Tappel and Bjornn (1983) also studied quality of chinook salmon spawning gravel and suggested assessment based on the percentages of sediments with diameters finer than 0.83 mm and finer than 9.5 mm out of the portion of the size distribution finer than 25.4 mm. The use of "eyed" eggs, however, likely increased survival in these studies (Tappel and Bjornn 1983) and may limit the usefulness of these data for comparison to survival in the field.

Positive VHGs (upwelling hyporheic flow) were observed on most sampling occasions at this redd and have been associated with spawning locations of chinook salmon (e.g., Geist and Dauble 1998). Negative VHG (downwelling flow) was observed

on a single occasion on 7 March (Figure 2). This was during a period of rainfall and was associated with increased stream flows. Malcolm et al. (2003) studied an anadromous salmonid spawning area in Scotland and observed positive VHGs associated with low flow periods and a reversal of VHG on the ascending limb of storm hydrographs. Malcolm et al. (2003) suggest that negative VHGs occur during periods of rainfall because the hydraulic head in the stream exceeds that of the surrounding groundwater, resulting in recharge, or passage of stream water to the bed. It is likely that the negative VHG observed in Deer Creek was indicative of the same sort of process. Positive VHGs in November and December appeared to be associated with surface water upwelling because surface water chemistry was similar to hyporheic chemistry (Tables 1 and 2). In March, however, a positive VHG was associated with large differences in surface and hyporheic chemistry (Tables 1 and 2). It is possible that a rising water table in March increased the groundwater flux through the hyporheic zone and generated differences in surface and hyporheic chemistry observed at that time.

Dissolved oxygen was low on one occasion (Table 1). Major mortalities were observed to occur in salmon eggs when D.O. dropped below 5 mg/L in Mill Creek just north of Deer Creek (Gangmark and Bakkala 1960). Dissolved oxygen concentrations near this minima were observed in the hyporheic portions of the sampler in March. Davis (1975) reviewed literature based on cause and effect information on oxygen requirements of salmonids and suggested a criterion level of 8.09 mg/L for mature eggs and larval salmonids as the point where an average member of the species will start to exhibit symptoms of oxygen distress. Chapman (1988), in a more recent review, concluded that any decrease in D.O. below saturation probably reduces survival to emergence or post-emergent survival.

Some trace elements were at concentrations that likely impact biota. Water concentrations of selenium (Se) of 2-5 μg/L are believed to affect fish (Lemly and Smith 1987) and a single value of 37.2 μg/L was noted in the bottom portion of a hyporheic pot in March (Table 2). Nickel (Ni) concentrations observed on a single occasion (Table 2) may also affect some organisms (Kszos et al. 1992) if concentrations are present for a long time. It is unclear from these data whether developing eggs or alevins would have been exposed to elevated concentrations of Se and Ni long enough to affect survival.

The relatively high densities of *Hydra* found in hyporheic pots is of interest since *Hydra* have been associated with increased mortality of larval fish (Eisler and Simon 1961, Elliott et al. 1997). High mortality of salmon alevins caused by *Hydra* has been observed in hatchery troughs even with as few as 20 *Hydra* in 500 mls of water (Eisler and Simon 1961). *Hydra* in our study, however, were only found in deeper portions of the hyporheic sampler and would be unlikely to encounter salmon alevins. Researchers have also suggested that salmonid eggs may be important food sources for invertebrates (McDonald 1960, Brown and Diamond 1984). Certain invertebrates, such as midges, are potential food for salmon fry and juveniles (Merz and Vanicek 1996). Eggs which do not survive may indirectly provide food to larval salmon by attracting invertebrates to the redd environment. The high densities of midges associated with dead eggs may allow for easy predation by larval salmon within the gravel (e.g., Dill 1969, Field-Dodgson 1988) and, after midge pupation, within the stream water column. Feeding by

alevins while they are still in the redd may be important for increased survival. This early transition to active feeding allows alevins to increase in size before final emergence from the gravel (e.g., Linley 2001). Heming et al. (1981) found that, when initial food presentation was delayed until alevins had completely absorbed the yolk, survival and biomass of chinook salmon was decreased.

Winter storms may also have a large negative impact on survival (Gangmark and Broad 1955). Gangmark and Bakkala (1960) found effects of stream runoff completely overshadowed other causes of egg mortality in Mill Creek, Tehama County, CA. It is likely that many of the problems that Gangmark and Bakkala (1960) observed in the 1950's with streambed erosion and deposits of silt and sand in redds are still occurring in some of these tributaries to the Sacramento River. The large amount of sediment deposited on the redd in this study may have affected embryo or alevin survival. Presently, however, there are no criteria on sediment accumulations that impact embryo survival or inhibition of alevin emergence from the redd (e.g., LaPointe et al. 2000).

This study was of a single salmon redd and data probably cannot be generalized (e.g., Malcolm et al. 2003) to other redds, even within Deer Creek. However, data suggest that hyporheic study of salmon redds may provide valuable information that could aid in understanding the environment of early life stages of salmonids. It is hoped that this paper will serve as a stimulus to further studies of this topic.

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THE OCCURRENCE OF THE WHITE SHARK, *CARCHARODON CARCHARIAS*, AT THE POINT REYES HEADLANDS, CALIFORNIA

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We present the results of a pilot study initiated during the fall of 2000 at the Point Reyes Headlands, a potential site for white shark research on the coast of California. The goal of this study was to determine if white sharks occur at this location. Ten sharks were observed during 45 h of sampling conducted between 9 October 2000, and 1 February 2001. Seven sharks were attracted to surface decoys deployed off of the headlands and three sharks were observed feeding on a whale carcass within Drake's Bay. No sharks responded to decoys presented within the Bay. Most sharks were observed early in the project, coincident with the presence of large numbers of young elephant seals.

INTRODUCTION

White sharks, *Carcharodon carcharias*, have long been known to frequent the waters adjacent to the haul-outs and breeding colonies of their pinniped prey (Ainley et al. 1981, 1985). In the eastern Pacific, primary prey species are believed to be Northern elephant seals, *Mirounga angustirostris*, and California sea lion, *Zalophus californianus*, (Ainley et al. 1981, Le Boeuf et al. 1982). Large colonies of these animals can be found at both the Farallon Islands, located 48 km west of San Francisco, and Año Nuevo Island, located 1 km offshore of the coast and 30 km north of Santa Cruz. Consequently, these two locations have been the site of significant white shark research (e.g. Farallon Islands: Klimley et al. 1992; Año Nuevo Island: Klimley et al. 2001a, b).

Recently, attention has been drawn to the Point Reyes Headlands as a potential site for white shark research. Point Reyes is a peninsula in Marin County, California, extending into the Pacific Ocean north of San Francisco. The entire peninsula is encapsulated by Point Reyes National Seashore (PRNS), and the adjacent waters are within the Gulf of the Farallones National Marine Sanctuary (GFNMS). The headlands, located at the extreme southern end of the Point Reyes peninsula, are typified by steep, granite and conglomerate bluffs (Galloway 1977) punctuated by occasional pocket

beaches which are all but inaccessible from land. Sea lions have long colonized the rocks in this area. In 1981, elephant seals colonized one of the headland beaches (see M, Fig. 1) (Allen et al. 1989). The colony started with three individuals, but has grown and now numbers approximately 1500 individuals (S. Allen, National Parks Service, personal communication). In 1986, elephant seals also established a smaller "satellite" colony (see S, Fig. 1) on a large sand beach in the sheltered northern end of Drake's Bay (S. Allen, personal communication). Elephant seals usually appear on this beach later in the season, generally after the primary beach reaches capacity or when winter storm activity forces subordinate animals off the beach. Nonbreeding elephant seals, typically juveniles or subadults, are also found scattered along the coast of Drake's Bay during the winter months. Since colonization, there has been evidence of white shark presence in this area including anecdotal observations of sharks and PRNS observations of seals with shark-inflicted wounds.

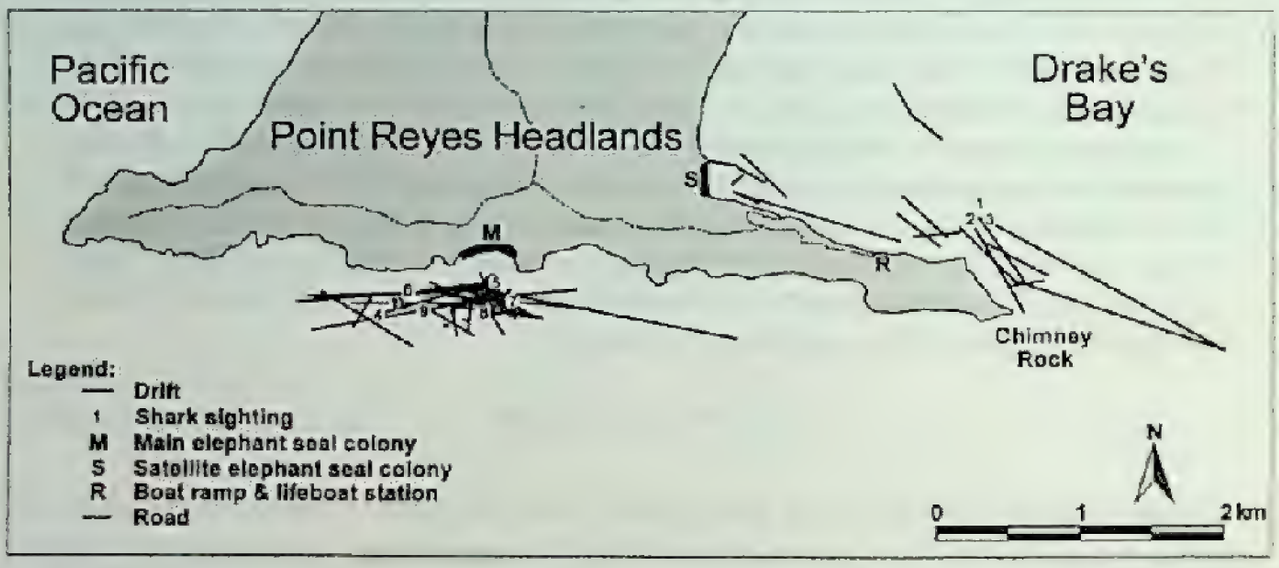

Figure 1. Map of Point Reyes Headlands area showing location of white shark sampling effort during 2000, in relation to elephant seal colonies (dark areas). Dark lines indicate locations of sampling drifts, and numbers indicate shark sightings (refer to *shark* column, Table 2).

Point Reyes is an ideal field location for a number of logistical and methodological reasons. There is easy mainland access to the area with paved roads leading almost directly to the elephant seal colonies. A small boat, equipment, and personnel can be conveniently transported directly to the field site, eliminating the need for large support boats. There is a boat ramp (see R, Fig. 1) adjacent to the historic lifeboat station in Drake's Bay, and the distance by boat from launch to the main colony is only 5 km. Additionally, there is easy shore access to overlooks from which to observe the seal beaches and the surrounding environs.

We initiated a pilot study of white sharks in this area in the fall of 2000. The goal of this project was to establish whether white sharks indeed occurred at the headlands and if they could be attracted to the surface with sufficient frequency to merit establishing more in-depth projects in the future.

METHODS

Late fall is typically the peak white shark observation and predation season at nearby Southeast Farallon Island (Ainley et al. 1981, Klimley et al. 1992, Pyle et al. 1996), so the pilot study began in October 2000. Two field days a week were scheduled and continued until the winter weather required that we remove our research boat from Drake's Bay. A typical field day began at 0800 hours. Elephant seals at the main seal colony were counted and photographed at this time from the best vantage point on the surrounding bluffs. No point provided a completely unrestricted view of the beach so we could not directly estimate the total number of seals present with complete confidence. However, by making our observations at the same location each day, we considered our estimate to be reflective of the actual number of individuals on the beach. We termed this estimate the Seal Index. Sampling work typically began off of the main colony during the morning hours when winds were typically calmest then moved back into the sheltered bay if conditions deteriorated.

The drifting decoy method (Anderson et al. 1996) was used to attract sharks to the surface. In this method, a wooden silhouette of a seal or sea lion is tethered to a line and drifted 25-30 m behind the research boat. Chum was not used to attract sharks, though in most cases small portions of a sea lion carcass, obtained from animals that had died of natural causes, were bound to the decoy providing some local chemical stimulus in order to entice investigating sharks to remain at the surface for longer periods of time. Sharks were not permitted to consume the carcass material in order to avoid positive reinforcement for the act of visiting objects at the surface. The use of natural prey in this manner was specified in both PRNS and GFNMS permits, and conducted with permission from the National Marine Fisheries Service.

Sampling was conducted primarily within the "high risk zone" (Klimley et al. 1992). This is the area adjacent to a seal colony extending from shore out to approximately 1.3 km, over relatively shallow water (<37 m), in which the majority of white shark predations are observed to occur. A location within this zone was selected based both on wind and ocean conditions and an attempt to sample throughout the research area. Once a location was selected, the decoy was deployed, the engine turned off, and the boat allowed to drift with the prevailing wind and current. Because of this, the duration, direction, and velocity of each drift were variable. Drift duration and distance varied from 7 min to 1.5 h, and 0.02 to 1.74 km, respectively. Latitude and longitude were recorded by GPS at the beginning and end of each drift.

Upon sighting a shark, the time and GPS position of the boat were recorded. The decoy was slowly pulled back to the boat in order to draw the shark closer for better observation as well as to prevent the shark from biting the decoy or feeding on the attached carcass. Observations were recorded on sex and distinguishing markings, focusing in particular on fin shape or unique features such as scars. Total length (TL) in meters was estimated based on comparison with objects of known length such as the decoy and the research boat, which was marked at meter increments for this purpose. Additionally, the shark was photographed while at the surface in order to establish an identification catalog of individual animals. Identification catalogs are a non-intrusive

means of long-term monitoring of white shark populations. Individual sharks may be identified on the basis of unique scars, markings, and dorsal and caudal fin shape (Anderson and Goldman 1996; Klimley and Anderson 1996). Observations continued until the shark departed, at which point the decoy was re-deployed and a new drift started.

RESULTS

Scavenging Event

On 2 October 2000, the fresh carcass of a dead male humpback whale drifted into Drake's Bay accompanied by scavenging white sharks. This was observed from shore until the carcass became beached and the sharks departed. On 9 October, the carcass was dislodged by the tide and began to drift back into the Bay. Fortuitously, our researchers were present at this time, in the process of preparing and launching our research boat for this project. Shortly after the carcass floated into the Bay, three sharks returned to feed (numbers 1, 2, 3 in Fig. 1 and Table 1). Observations of this event will be detailed in a separate paper; however, some results are included here as the sharks present were included in our identification catalog.

Table 1: Summary of white sharks sighted and data collected at Point Reyes, California, 2000.

Shark	Date	Time	Latitude	Longitude	Site	Sex	Length (m)	Photo
1[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	m	4.5	y
2[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	f	3.5	y
3[a]	9 Oct. 2000	15:30	38°00'00"N	122°58'12"W	D	-	3.5	y
4	16 Oct. 2000	12:57	37°59'24"N	123°00'15"W	H	-	3.5	y
5	16 Oct. 2000	14:20	37°59'32"N	122°59'48"W	H	-	-	n
6	17 Oct. 2000	11:45	37°59'30"N	123°00'08"W	H	-	3.5	y
7	24 Oct. 2000	10:43	37°59'28"N	122°59'44"W	H	-	-	n
8	20 Nov. 2000	9:49	37°59'25"N	122°59'51"W	H	-	3-3.5	n
9	20 Nov. 2000	11:54	37°59'25"N	123°00'05"W	H	f	3.0	y
10	1 Feb. 2001	11:12	37°59'27"N	123°00'11"W	H	-	3.5-4	y

[a] Prior to start of sampling effort

Table key: *Site*: D = Drake's Bay, H = Headlands; *Sex*: sex of shark if known; *Length*: estimated total length if available; *Photo*: was the shark photographed?

Main Survey

Starting on 16 October and continuing through 12 December, field work commenced on the planned schedule. Fourteen days were spent in the field during this period. A break in winter storms permitted an additional field day on 1 February 2001. Daily sampling efforts and results are summarized in Table 1. During these 15 d, approximately 45 h were spent sampling. We define "sampling" to mean time spent actively searching for sharks with the decoy in the water. During this time, we sampled over a linear distance in excess of 29 km, measured between starting and ending points of each drift. Of this, over 32 h covering 18 km were spent at the headlands in the general area of the main seal colony (see M, Fig. 1). An additional 12 h, covering 11 km, were spent within the confines of Drake's Bay (note: this includes 4 h of observation of the whale carcass with no decoy present). The drifts in Drake's Bay were distributed over a greater area than those off the headlands. Some drifts were conducted off the site of the satellite elephant seal colony, though no elephant seals were on the beach during the study period; however, harbor seals, *Phoca vitulina richardsi*, were present. This area is very shallow (<3 m) with a sand bottom. The lack of both preferred habitat and primary prey species convinced us to direct our efforts elsewhere. Other drifts within Drake's Bay occurred along the rocky area between the boat ramp and Chimney Rock, which forms the easternmost spur of the headlands. This region was where the whale scavenging took place, and thus the occurrence of white sharks there was believed to be likely.

A total of 10 white sharks was observed between 9 October 2000, and 1 February 2001 (Table 2). Of these, three sharks were observed feeding on the whale carcass within Drake's Bay. The remaining seven sharks were attracted to our decoy, and all were observed off of the headlands (Fig. 1). This equates to a sighting frequency off the headlands of one shark per 4.75 h of sampling. The number of sharks sighted per week does not appear to be related to the total number of hours spent sampling that week (Fig. 2). For example, in the week of 14-20 October, three sharks were sighted during only 5.25 h of sampling. In contrast, we saw no sharks the week of 4-10 December, despite calm seas and perfect weather, which permitted 14 h of sampling.

The number of sharks sighted was roughly related to the size of the seal colony on the beach (see Seal Index, Fig. 3). The highest number of seals were counted (approximately 300 individuals) during the first week of the project. Most of these seals were yearlings. The index declined sharply in the following weeks to about 100 individuals before beginning to increase again to about 150 as sub-adults and adults began to arrive on the beach. With the exception of one sampling day on 1 February, sampling ended prior to the arrival of the majority of the adults and the commencement of the breeding season. Further, no elephant seals were observed inside Drake's Bay on the weeks for which seal data are available. Coincident with the initially high numbers of juvenile elephant seals, our decoy attracted three of the seven total sharks in the first week, and four of the seven in the first 2 weeks. The arrival of adult seals, first noted during late November, seems to be matched by the sighting of two sharks during the week of 18-24 November. However, we have no explanation for the paucity of sightings in the subsequent weeks, particularly since the weather during one of those weeks (4-10 December) was good, the seas calm, and sharks easily detected, if present.

Table 2: Summary of white shark survey effort at Point Reyes, California, 2000. Effort is subdivided into drifts near the Headlands and within Drake's Bay.

	Headlands drifts					Drake's Bay drifts					
Date	Start (h:m)	Stop (h:m)	Duration (h:m)	Distance (km)	Sharks	Start (h:m)	Stop (h:m)	Duration (h:m)	Distance (km)	Sharks	Decoy
9 Oct. 2000[a]	-	-	-	-	-	13:30	17:30	4:00	N/A	3	N/A
16 Oct. 2000	10:45	15:18	3:12	2.0	2	-	-	-	-	-	sea lion
17 Oct. 2000	11:24	12:06	0:21	0.4	1	12:44	15:22	1:45	4.0	-	sea lion
23 Oct. 2000	-	-	-	-	-	10:25	14:00	1:42	0.9	-	elephant seal
24 Oct. 2000	9:33	15:40	4:40	5.4	1	-	-	-	-	-	elephant seal
31 Oct. 2000	10:35	11:05	0:30	ND	-	-	-	-	-	-	elephant seal
7 Nov. 2000	9:22	10:35	0:45	0.6	-	11:30	14:45	2:23	4.0	-	elephant seal
13 Nov. 2000	9:21	10:26	0:36	0.5	-	-	-	-	-	-	elephant seal
20 Nov. 2000	9:13	14:10	4:30	1.1	2	-	-	-	-	-	sea lion
22 Nov. 2000	-	-	-	-	-	9:56	11:02	0:56	0.1	-	sea lion
4 Dec. 2000	9:21	14:40	4:45	2.9	-	-	-	-	-	-	sea lion
5 Dec. 2000	9:16	15:14	4:42	1.1	-	-	-	-	-	-	sea lion
8 Dec. 2000	9:12	14:05	4:15	1.9	-	-	-	-	-	-	elephant seal
12 Dec. 2000	10:15	12:50	2:05	1.9	-	13:25	14:58	1:15	1.9	-	elephant seal
1 Feb. 2001	10:28	13:01	2:19	0.5	1	-	-	-	-	-	sea lion
Total			32:40	18.2	7			12:01	10.9	3	

[a] Observations at whale carcass prior to start of sampling effort

Table key: *Start*: time when decoy was first introduced to water; *Stop*: time when decoy was last removed from water; *Duration*: total time spent with decoy in the water; *Distance*: sum of linear distance between drift start and stop points; *Sharks*: number of confirmed observations of white sharks; *Decoy*: shape of silhouette; *N/A*: not applicable; *ND*: no data.

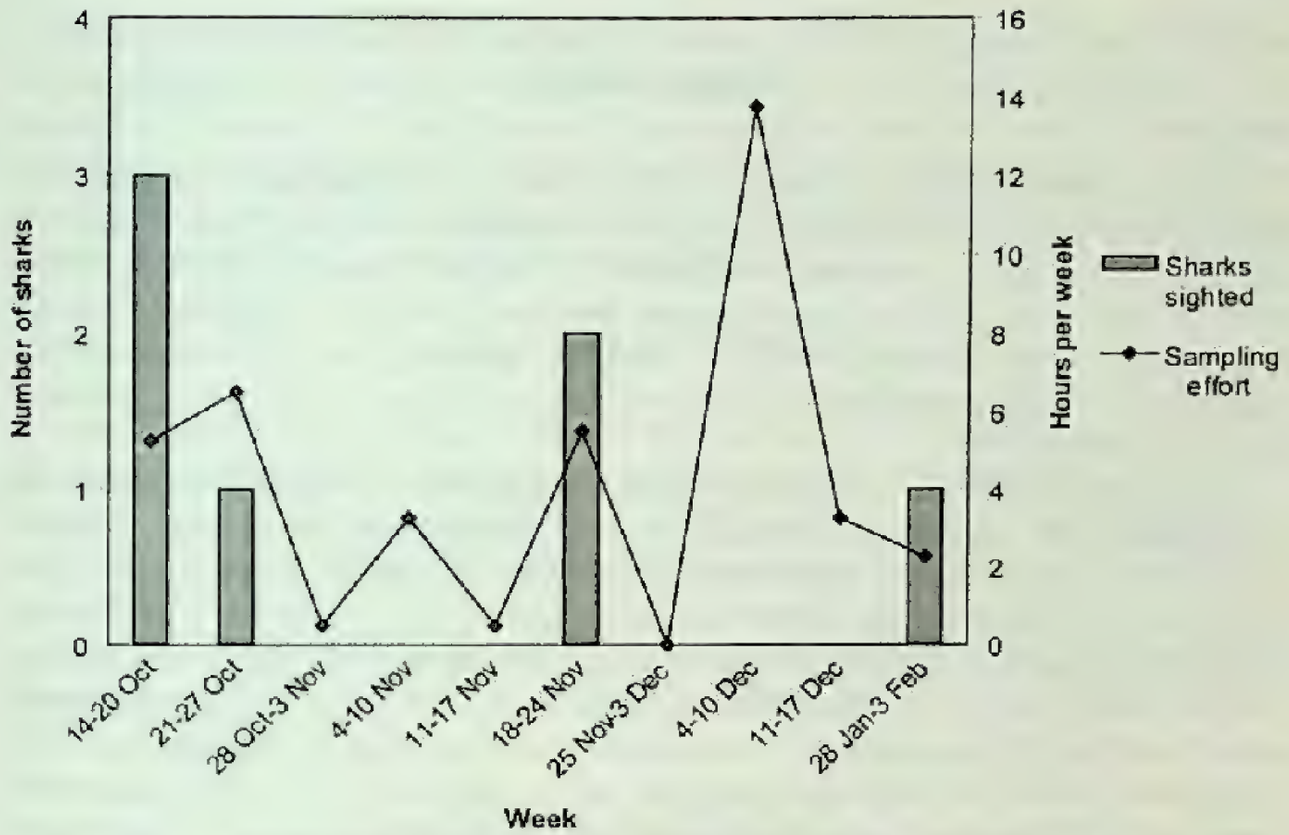

Figure 2. White shark sampling effort at the Point Reyes Headlands, California, 2000. Hours per week (black line) are compared to shark sightings (gray bars).

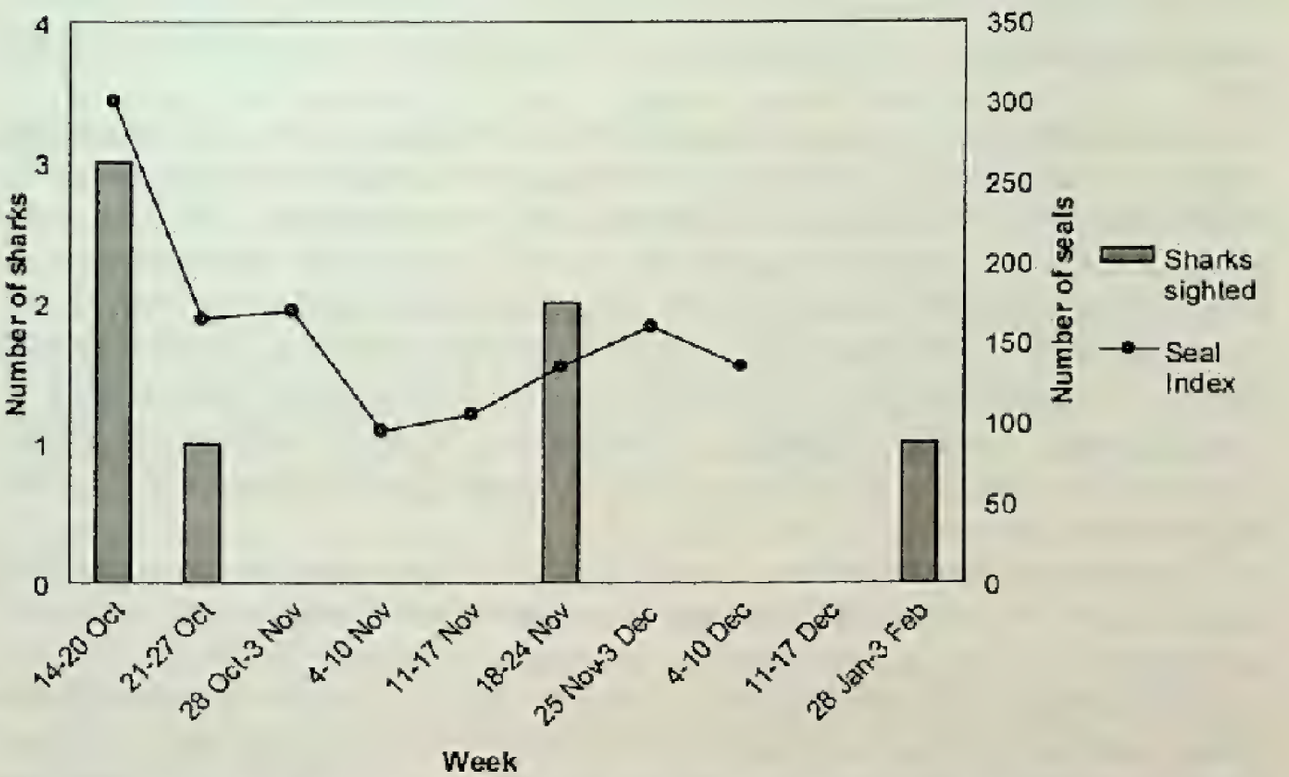

Figure 3. Seal Index (black line) recorded at the Point Reyes Headlands, California, main elephant seal colony during fall 2000 contrasted with shark sightings (gray bars) during the same period. Seal Index data are not available for the final two weeks of the project.

DISCUSSION

White sharks are clearly present at the Point Reyes Headlands. Further, it is apparent that they can be attracted to the surface using conventional techniques. We sighted an average of one shark for every 4.75 h spent sampling. This equates to roughly one shark per day on the water; however, the shark sightings were not distributed evenly over time (Fig. 2). It must be cautioned, too, that the sample size thus far is too small to draw final conclusions; however, some trends are suggested and are worth noting.

One point of interest is that white sharks are present in these waters beyond the time period from September to December when yearling elephant seals are typically present. We expected shark occurrence to peak with the return to shore of these naïve animals, as has been reported at the Farallon Islands (Ainley et al. 1981, 1985). Our project began during this season, and there appears to be some correlation between the Seal Index and the number of sharks sighted (Fig. 3). However, one shark was attracted to the surface as late as 1 February 2001, during only 2.25 h of sampling. This suggests that while shark numbers may peak during early fall, some animals are present much later. This raises the question of whether or not white sharks are in fact present year round, perhaps targeting resident sea lions or harbor seals as prey. Such a pattern was first suggested by Ainley et al. (1985) at Double Point and has been noted at the Farallon Islands (P. Pyle, Point Reyes Bird Observatory, personal communication). Of interest, then, would be to determine if the sharks observed at the headlands during the elephant seal haul-out season were the same animals observed in that area the rest of the year, or if there are different aggregations of sharks present at different times of year.

Another point worth noting is that all white sharks observed in this project were smaller animals (Table 2). The largest, a male of approximately 4.5 m, was sighted at the whale carcass; however, the majority of the sharks were in the range of 3.5 to 4 m, with one small individual of approximately 3 m. It is likely that at least the smallest shark, believed to be female, was subadult based on a reported size at maturity of 3.5 m for males (Pratt 1996) and 4.5 m or greater for females (Francis 1996). This is in contrast to regular sightings of adult individuals of 5-6 m at Southeast Farallon Island, approximately 33 km to the south. It unknown whether the small size of the sharks at PRNS is an artifact of the small number of observations, or if this reflects an unusual feature of the shark population in that area.

The results of this study raise a number of intriguing questions, each meriting further study. Are white sharks present at the Point Reyes Headlands year round or seasonally? How long do individual sharks remain in the area? Do sharks sighted at the headlands appear at the Farallon Islands too? Are the same sharks present for the yearling elephant seal haul-out season as are present for the adult seal breeding season or the harbor seal breeding season? Do the headlands actually attract smaller sharks than nearby sites, and if so, for what reason? Are larger sharks excluding smaller sharks from the rich hunting grounds of the Farallon Islands, forcing the younger individuals to the smaller colony at Point Reyes?

The many conveniences offered by the location, and the success we met in locating sharks, suggest that Point Reyes can be an excellent site for future research on white sharks and their prey. We look forward to expanding on what we have already begun as well as initiating more detailed studies, and believe that the development of this new location will compliment other established sites in California and further our understanding of this important marine predator.

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RECORDS OF THE EXOTIC FRESHWATER AMPHIPOD, *CRANGONYX PSEUDOGRACILIS*, IN SAN LUIS OBISPO COUNTY, CALIFORNIA

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The introduction of exotic invertebrates into California's aquatic habitats is of special concern because of their potential impact on native species. In California, the benthic invertebrate fauna of San Francisco Bay and the Sacramento-San Joaquin Delta has been greatly modified by the invasion of several hundred exotic species (Carlton 1979, Cohen and Carlton 1995). This non-indigenous fauna has been extensively documented, but fewer reports exist of exotic invertebrates introduced into California's smaller freshwater streams and lakes. In this paper, we report the discovery of the freshwater amphipod, *Crangonyx pseudogracilis* Bousfield, 1958, in Brizzolara and Stenner creeks, small streams flowing through the City of San Luis Obispo, San Luis Obispo County, California.

Forty-two species of *Crangonyx* inhabit North American freshwaters, most having limited distributions in surface and underground aquatic habitats east of the Rocky Mountains (Holsinger 1972, Zhang 1997). Only one native species occurs in the Pacific States, *C. richmondensis* Ellis, 1940, known primarily from Oregon and Washington, but with one collection from Sonoma County, California (Zhang 1997).

While most *Crangonyx* species have small ranges, a few species are widely distributed in eastern North America and apparently possess adaptations well suited to long-distance dispersal by human activities (Zhang 1997). For example, Toft et al. (2002) recently reported the introduction of *C. floridanus* Bousfield, 1963, into the Sacramento-San Joaquin Delta, California. *Crangonyx pseudogracilis* has a wide natural distribution from SE Canada to Texas. In recent decades, this species has expanded its native range, being introduced by humans into other areas of the United States and into European freshwaters (Costello 1993, Zhang 1997, MacNeil et al. 2001).

We first collected *C. pseudogracilis* in Stenner Creek, San Luis Obispo, California, in January 2002. During March-April 2002, we searched nearby stream and pond locations within the Stenner and Brizzolara Creek watersheds to determine the present distribution of *C. pseudogracilis* and of the native amphipod *Hyalella azteca* (Saussure, 1858) species complex. These collections extended over 8 km of stream habitat and several small ponds within the urban area of San Luis Obispo and north into the foothills of the Santa Lucia Range. From 19 collecting locations, no amphipods were found at 8 sites, *C. pseudogracilis* only was found at 4 sites, *H. azteca* only was found

at 5 sites, and both species co-inhabited 2 sites.

Crangonyx pseudogracilis was collected only in stream habitats in the lower section of Stenner Creek and a small upstream tributary, Brizzolara Creek, which flows through the campus of California Polytechnic State University. In contrast, the upper reaches of Stenner Creek and nearby ponds contained only *H. azteca*. Both amphipod species inhabited the lower reaches of Brizzolara Creek just above its confluence with Stenner Creek. Thus, *C. pseudogracilis* is presently confined to the urbanized Brizzolara-Stenner Creek continuum in San Luis Obispo, and apparently has not expanded into nearby ponds or the more rural upstream reaches of both creeks. At the two sites where both species co-occurred, *C. pseudogracilis* was abundant and *H. azteca* was rare. *Crangonyx pseudogracilis* was the dominant amphipod along the Brizzolara-Stenner Creek continuum and may be excluding the similarly-sized *H. azteca*. Since our *C. pseudogracilis* collections contained adult females carrying eggs, adult males, and juveniles, this species is actively reproducing in the Brizzolara and Stenner Creek watersheds.

Both Brizzolara and Stenner Creeks are small urban streams, being 1-3 m wide and 15-50 cm deep. These streams flow into San Luis Obispo Creek and are located 15 km upstream (elevation 60-180 m) from the ocean at San Luis Obispo Bay. Stream discharge varies seasonally, with higher flows during winter and early spring, and low or intermittent flows during summer and autumn. During our March-April collections both creeks had intermittent flow. Water temperatures were 7-15°C. Stream substrates ranged from fine organic detritus to coarse gravel and pebbles.

We do not know how or when *C. pseudogracilis* was introduced into Brizzolara and Stenner creeks, but its present distribution suggests an entry near the California Polytechnic State University campus. While downstream dispersal of amphipods can occur quickly with the stream's current, upstream dispersal against a swift current is more difficult. With sufficient time, amphipods can extend their range upstream by crawling along the substrate and swimming. Because of several small dams and water control structures with vertical drops in both creek channels, upstream dispersal would be especially difficult for amphipods in these drainage systems. If *C. pseudogracilis* was introduced relatively recently and has had little time for upstream dispersal into the upper Stenner Creek watershed, our collection of this amphipod in Brizzolara Creek may be near the original site of introduction. Interestingly, the land adjacent to Brizzolara Creek was used for many years to hold livestock imported from all regions of the United States and discarded stock water harboring *C. pseudogracilis* may be the source of introduction. While many of California's exotic aquatic invertebrates arrived in ship ballast water (Cohen and Carlton 1995), this transit mode appears unlikely for the Brizzolara and Stenner Creek introduction since a shipping port does not occur in the estuary downstream.

Voucher specimens of *C. pseudogracilis* have been deposited at the California Academy of Sciences, San Francisco, California, and in the amphipod collection at Old Dominion University, Norfolk, Virginia. Dr. John R. Holsinger, Old Dominion University, confirmed the identification of *C. pseudogracilis*.

Collecting Data: San Luis Obispo County, California

***Crangonyx pseudogracilis* only**

Stenner Creek at Olive St, 20 Jan 2002 (5 specimens); 31 March 2002 (10); 1 April 2002 (38); 19 Jan 2003 (26)
Stenner Creek at Brizzolara Creek confluence, 4 April 2002 (15)
Brizzolara Creek at N side of Highland Drive and railroad tracks, 6 April 2002 (2)
Brizzolara Creek at Highland Drive, 100 yards E of railroad tracks, 6 April 2002 (9)

***Hyalella azteca* only**

Stenner Creek Ranch pond, N of Stenner Creek Road, 2 April 2002 (12)
Pond below water treatment plant, W of Stenner Creek Road, 2 April 2002 (1)
Stenner Creek at N end of Stenner Glen, 4 April 2002 (5)
Stenner Creek at Highland Drive, 5 April 2002 (4)
California Polytechnic State University water delivery pond, 6 April 2002 (25)

Crangonyx pseudogracilis* and *Hyalella azteca

Brizzolara Creek at Mustang Village bridge, 5 April 2002 (31 Cp, 1 Ha)
Brizzolara Creek at Highland Drive, 5 April 2002 (19 Cp, 1 Ha)

No Amphipods Found

Brizzolara Creek at Botanic Gardens, 1 April 2002
Brizzolara Creek at Highland Drive, 200 yards E of railroad tracks, 1 April 2002
Stenner Creek just below Stenner Ranch pond, N of Stenner Creek Road, 2 April 2002
Stenner Creek 200 yards above railroad tracks, 3 April 2002
Upper pig settling pond #1, N of railroad tracks, 3 April 2002
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Brizzolara Creek 150 yards E of railroad tracks, 6 April 2002
Brizzolara Creek at Via Carta, 6 April 2002

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FIRST RECORD OF THE PACIFIC DOG SNAPPER, *LUTJANUS NOVEMFASCIATUS*, IN CALIFORNIA

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On 23 January 2001, a Pacific dog snapper, *Lutjanus novemfasciatus* Gill (Fig. 1), was taken by spear near Morro Bay, California. The fish was captured in approximately 4 m of water within the warm-water discharge channel of the Duke Energy power plant, just north of Morro Rock. The fish was taken near a large cave hovering above an assorted rock and sand bottom. The specimen measured 29.25 inches, (743 mm) standard length; 33.25 inches, (845 mm) total length, and weighed 19 lb 6 oz (8.788 kg.). Its body coloration was brown above to bronze below. The canine teeth were extremely impressive, with the largest tooth was longer than the pupil diameter of the eye. The distinct bars that are common in younger individuals were not apparent. The pectoral fins were moderate in length, reaching beyond the pelvic fins but falling far short of the anus.

Lutjanus novemfasciatus has been referred to as Pacific dog snapper or pargo prieto (Thomson et al. 2000). The fish was examined by Robert Hardy, biologist, California Department of Fish and Game, approximately 20 minutes after capture. The specimen was not preserved although both upper and lower jaws, otoliths, and skin samples, including scales, were retained. Photographs were taken for identification and documentation purposes.

This specimen represents one of only three species of the family Lutjanidae taken off California. I observed one other Pacific dog snapper approximately 1 month earlier near the same location, but failed to secure it after it pulled free from my spear shaft. These two individuals were obviously distinct as the harvested specimen showed no wounds or scars, which would have resulted from the previous spearing attempt.

Figure 1. *Lutjanus novemfasciatus* taken near Morro Bay, California 23 January 2001.

Lutjanus novemfasciatus occurs throughout the Gulf of California to Peru (Thomson et al. 2000). According to this range, the specimen taken near Morro Bay, California was taken approximately 1080 miles (1740 km) north of the previously recorded northernmost distributional range of the species. However, in 1952, John Fitch (1952) reported on a Pacific dog snapper taken from Santa Maria Lagoon on the outer coast of Baja California. This report was apparently overlooked by Thomson and thus places the *Lutjanus novemfaciatus* taken near Morro Bay approximately 900 miles (1450 km) north of the previously recorded northernmost distributional range of the species.

The *Lutjanus novemfaciatus* taken near Morro Bay represents the fourth member of the family to be reported from California. Other members include *Lutjanus colorado* taken in 1976, (Lehtonen 1979) *Lutjanus argentiventris*, taken in 1977 (Phelan 1983), and *Lutjanus peru*, reported in 1991 (Robins et al. 1991).

Examination of the scales showed six distinct growth rings corresponding to six summer/winter cycles. Otolith examination confirmed these findings, as they contained six hyaline zones and the start of an opaque margin.

It is significant that the fish was taken in the Morro Bay Duke Energy power plant discharge canal, where the water temperatures are an average of 7° C (19° F) higher than ambient water temperatures (PG&E 1983[1]). This elevated water temperature may have drawn the fish in, as the temperatures are closer to those where *Lutjanus novemfasciatus* is normally found.

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[1]Pacific Gas and Electric. 1983. Nov. Morro Bay Power Plant Cooling Water Intake Structures. Ecological Analysts, Inc. Report PGE60B1. 2-1-2-12.

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